FLARE-RELATED COLOR EFFECTS IN UV CETI STARS

By

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To my late Grandpa Homan,

who, some 20 years ago, first turned my gaze to the stars.

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FLARE-RELATED COLOR EFFECTS IN UV CETI STARS

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The UV Ceti flare stars YZ CMi, BD+16°2708, EV Lac, and AD Leo were monitored photoelectrically for flare activity with the 76 centimeter reflecting telescope of the University of Florida's Rosemary Hill Observatory. Observations were carried out from January, 1973 to April, 1975. The instrumentation allowed simultaneous readings to be taken at 3500, 4632, and 6496 Å with a time resolution of 2 seconds. A total of 15 major events were observed, with 14 of these being observed in all three colors. All events showed the classical fast rise and slower decline that is typical of this type of activity. One event showed peculiar behavior in the red bandpass that may indicate strong dependence of the flare light in some cases on line emission.

The data were applied to the fast electron model of flare activity proposed by Gurzadyan. Several serious

inconsistencies in the theory were found that would not have been evident in single-channel monitoring. No event could be fitted in all three colors using consistent values of the unknown parameters in the theory. The most serious deficiencies in the theory were the wavelength dependence of the optical depth of the electron cloud and the lack of treatment of line emission behavior.

Differential color indices for flare light are calculated and are shown to be essentially constant throughout the entire event for the stronger flares. A color-color plot of the flare light at maximum reveals that 11 of the flares show a linear relation. This relation indicates that the smaller the u-b index, the larger is the b-r index. This is probably directly involved with line emission during flare events.

Future research possibilities are discussed, with spectroscopic studies and simultaneous multicolor observations being stressed.

CHAPTER I

INTRODUCTION AND HISTORY

Introduction

UV Ceti flare stars comprise one of a number of types of eruptive variable stars, including supernovae, novae, U Gem stars and others. The outbursts of flare stars are the least energetic and have the shortest duration of all the various types of eruptive phenomena in nonstable stars. The class is comprised predominantly of red dwarf stars of spectral class M, and therefore are among the most intrinsically faint stars in the Galaxy, occupying a place on or near the faintest portion of the main sequence (Gershberg 1967; Lippincott 1953; Morgan 1938).

Because of their intrinsic faintness, the vast majority of known flare stars lie within 20 parsecs of the sun. In fact, flare stars constitute an appreciable percentage of stars within 20 parsecs of the sun. The fact that our sample is fairly complete in this region implies that UV Ceti stars may represent one of the most numerous types of variable stars in the Galaxy.

The outbursts seen in flare stars have durations of a few minutes and probably originate from only a portion of

the star's surface. The energies involved in flare activity are comparable to those of solar flares, releasing about 10^{31} ergs in the optical part of the spectrum (Gurzadyan 1971; Gershberg 1973).

The flare light itself is much bluer than the radiation from the quiet star. Line emission and photometric colors of flare light indicate temperatures at the flare site in excess of 10,000 K. Since the photospheric temperatures of flare stars are in the neighborhood of 3000 K, the relative change in the brightness of the star is much greater at the shorter wavelengths. For this reason, the ultraviolet is the best region of the spectrum in which to look for flare activity (Joy 1960; Kunkel 1967; 1970). However, due to the late spectral class and the apparent faintness of these stars (especially in the ultraviolet), photometry in this band is difficult and prone to large uncertainties.

Optically, flares are characterized by a very rapid rise to maximum intensity. The time required for this rise is typically only tens or hundreds of seconds. The peak of the light curve is usually sharp and the quasi-exponential decay is more gradual than the rise, taking several minutes. Very rarely will the decline be more rapid than the rise to maximum. The light curve may also exhibit secondary peaks, periods of constant brightness, and sudden drastic changes in slope. Less frequently, the maximum is very rounded and indistinct, making the measurement of the time of maximum

difficult. Occasionally the intensity of the star will increase or decrease a small amount before the rapid rise to maximum begins.

Flares are also distinctive spectroscopically. The spectrum of the quiet star typically shows several emission features, most common of which are the hydrogen Balmer lines and the Ca II H and K lines (Roques 1955). During a flare, the emission lines are enhanced and many of the absorption lines at the blue end of the spectrum can be completely washed out. Other emission lines may appear in the spectrum, most frequently those of helium. The enhancement of the emission lines can last much longer than the enhancement observed in the wide-band photometry observations, being conspicuous in many cases long after the photoelectric light levels return to normal. Bopp and Moffett (1973) have found that the Balmer lines can contribute 16 per cent of the flare intensity in the B bandpass, and Flesch and Oliver (1974) have reported an event that may indicate that Hα in some cases dominates the stellar intensity near 6500Å (Mullan 1974). However, the increase in intensity in typical broad-band photometry is primarily due to enhancement in the continuum radiation (Joy 1954; 1957; Struve 1959; Oskanian 1968; Ambartsumian and Mirzoyan 1971).

At least some flare stars show slow quasi-periodic variations of a few hundreths of a magnitude in addition to their flare activity (Kron 1952; Roques 1958; Torres,

Mello, and Quast 1972; Bopp and Evans 1973; Torres and Mello 1973; Martins 1974; Mullan 1974). These spots are very possibly associated with stellar flares in much the same way as sunspots are with solar flares. This idea is supported by observations of ultraviolet excesses when these secondary variations are at a minimum light phase. Presumably the activity associated with the spot region is visible at these times.

History

The intrinsic faintness of flare stars and the rapid nature of the events have made the study of these stars a comparatively recent endeavor in astronomy.

In 1924 Hertzsprung noted a dramatic increase in brightness on one of a series of photographs of the star later to become known as DH Carinae. The rate of increase in intensity was too great for the star to be a nova or an RR Lyrae star, so Hertzsprung postulated that an asteroid had fallen into the star, causing the increase in brightness. We now know that this was one of the first observations of a stellar flare, though it would take about 25 years from the time of Hertzsprung's observation for the astronomical community to officially recognize the existence of stellar flares.

Observations of flares were so infrequent during the next few decades that each observation warranted a publication.

Indeed, not until 1950 did the International Astronomical Union officially recognize UV Ceti stars as a separate class of variable star (Bateson 1971).

One of the more important early observations of a stellar flare was made late in 1948. The faint red star L-726-8 had been found to have a large proper motion, thereby being a good candidate for parallax measurements. Page and Struve obtained spectra of the star and determined its spectral class to be M6 with hydrogen and calcium in emission. Joy and Humason (1949) found the star to be double with a separation of about 1.5 arc seconds. Carpenter took parallax plates on December 7, 1948 and found that one of the five images of the star was much brighter than the other four. The conclusion was reached that the fainter component of the system had undergone a flare. In three minutes the star had increased in brightness by about 3 magnitudes. The star was consequently named UV Ceti and became the prototype for this class of variable (Luyten 1949).

Beginning in 1949, photoelectric light curves of flares have provided much information about the general characteristics of these events. Unfortunately, the vast majority of this monitoring has been done in only one spectral region. While this provides information as to the frequency and strength of the outbursts, it provides little insight into the physics involved. Several observatories have recently begun using photometers equipped with filter wheels which allow rapid interchanging of filters, resulting in multicolor

observations of flare events. However, several problems are present in this type of monitoring. The major difficulty lies in the fact that if three filters are employed in such a system, then at best only 1/3 of the observing time is spent in any one color. This effectively cuts down the amount of flux which defines each observation by at least a factor of three. Also, since the measures are not really simultaneous, it becomes necessary to interpolate or extrapolate on the light curve to obtain the observed color of the flare light at any particular epoch. Truly simultaneous multicolor observations were needed, and it was with this in mind that the flare star program at the University of Florida was planned.

CHAPTER II

INSTRUMENTATION AND TECHNIQUES OF OBSERVATION AND DATA REDUCTION

The accurate investigation of flare-related color effects in UV Ceti stars puts restrictions on the type of equipment used that are not encountered in most photoelectric programs. Because of the short duration of the events and the rapid changes that occur in the light curve, high time resolution is essential. The observations must also be truly simultaneous, since interpolations and extrapolations over the rapidly changing light curve would introduce a major source of uncertainty. These considerations necessitate a multichannel photometer rather than one using interchangable filters. Also, due to the low light levels inherent in the study of dMe stars, especially in the ultraviolet, the light beam must be split into the various bands in the most efficient way possible.

The apparatus designed and built to meet these considerations consisted of a three-channel photometer using ultraviolet reflection filters and two interference filters as dichroic mirrors. The reflected beam from an Optics Technology interference filter #621 was used to isolate the ultraviolet band. This beam was then reflected from three

Schott-Mainz UV-R-347 reflection filters to cut down on the side lobes. This particular ultraviolet bandpass was chosen in order to isolate as much as possible the region of the spectrum to the short wavelength side of the Balmer discontinuity. The transmitted beam from the #621 filter was split using the Optics Technology interference filter #4540. The reflected portion of this beam was used in defining the blue band and the transmitted portion the red band.

EMI 6256B photomultiplier tubes were used for the ultraviolet and blue bands. An EMI 9658B photomultiplier tube was used for the red band. This combination of filters and tubes defined the three bandpasses shown in Figure 1.

This system allows simultaneous readings to be made in three separate spectral regions. It therefore enjoys a great advantage over the interchanging filter technique, since 100 per cent of the monitoring time is spent in all colors. In addition, the use of the interference filters as dichroic mirrors gives very high efficiencies in separating the star light into the three spectral regions. This increase in efficiency can be seen by comparing the quantum efficiencies of the three-channel system with those of the UBV standard system shown in Figure 2. The photometer system is schematically shown in Figure 3.

All observations were made with the 76 centimeter reflecting telescope of the University of Florida's Rosemary Hill Observatory (RHO). The telescope was used at the f/16 Cassegrain focus. Data consisting of the Julian Day number,

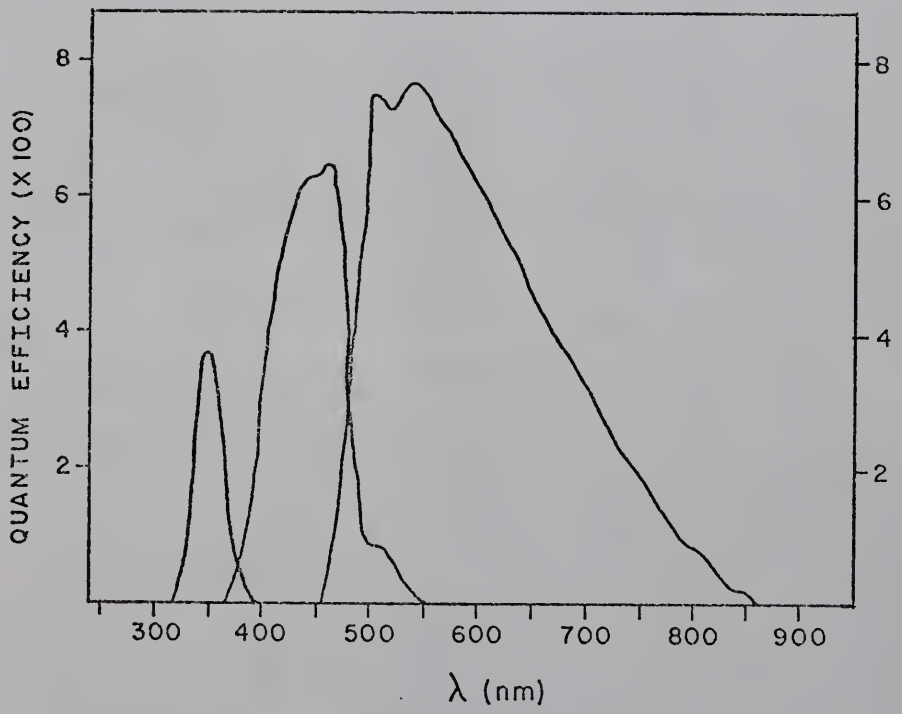


Figure 1 - Spectral response of the three-channel photometric system used in flare star monitoring.

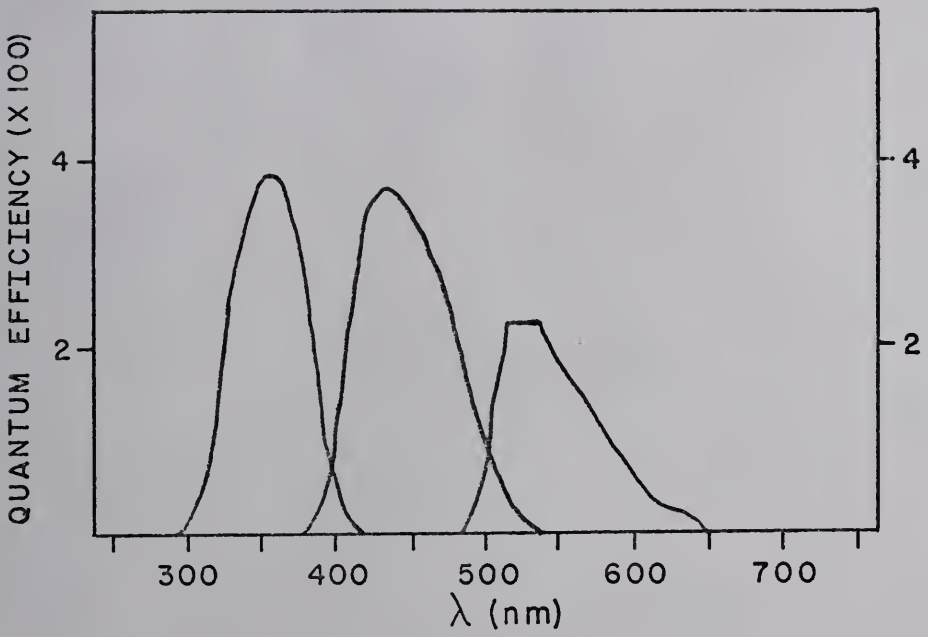


Figure 2 - Spectral response of the standard UBV system in use at RHO.

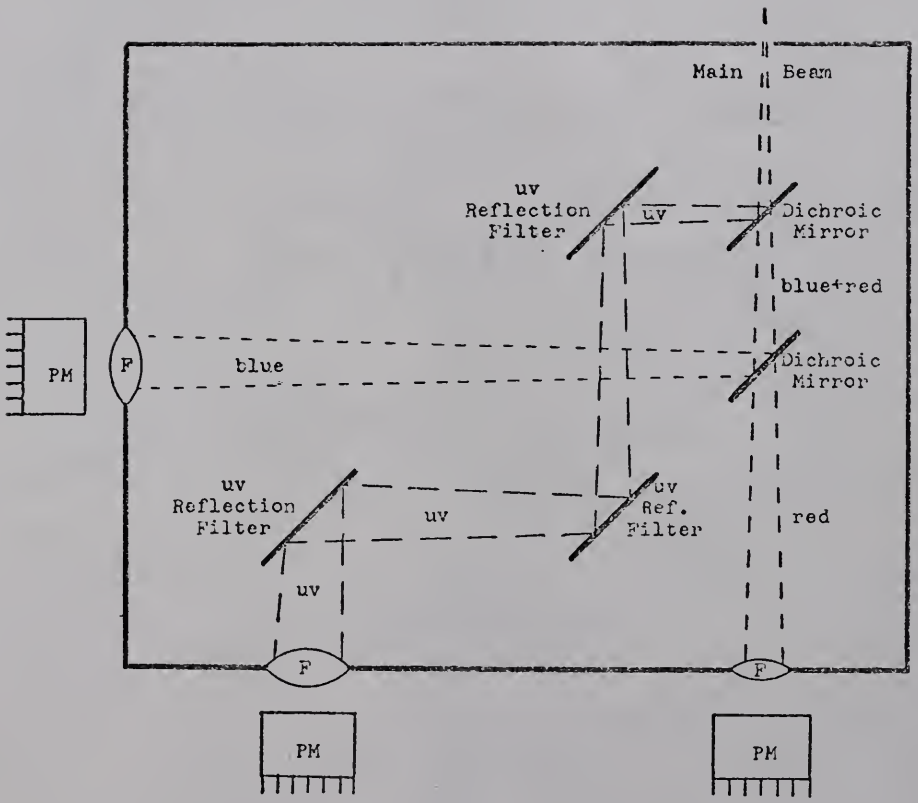


Figure 3 - Schematic diagram of the three-channel photometer including Fabry lenses(F) and photomultiplier tubes(PM).

intensity readings, length of integration, Universal Time, and other coded information were recorded on magnetic tape using a DigiData 7 track 200 BPI magnetic tape unit. A Honeywell chart recorder was used to monitor the ultraviolet channel during observation.

Observing Techniques

The data-taking system used in the observing program allowed a series of readings to be taken continuously with a dead time between integrations of approximately 0.1 second. The integration times used were typically 2 to 3 seconds because of the high noise level in the ultraviolet signal.

Star readings were taken continuously except for breaks for sky readings at intervals of about 30 minutes and checks on the centering of the star in the diaphragm every 5 to 10 minutes. Few if any observations were made of comparison stars, the quiet level of the stellar intensity being used as a reference for all activity. This procedure was chosen to maximize the time of coverage on the variable because of the unpredictability of flare activity. With this type of monitoring, 90 to 95 per cent of the time was spent in actual observation of the variable.

All data were recorded by the magnetic tape unit. The chart recorder was used only as a visual check on activity. Chart readings were not used in the reduction of the data.

The photomultiplier tubes were operated at 1000 volts.

The ultraviolet and red channels were maintained at dry ice temperatures, whereas the blue channel was cooled by an EMI ZD-50 thermoelectric chamber to a temperature of approximately 0° C. The signal from each tube was fed to a separate standard RHO electrometer amplifier (Oliver 1975).

A 23.6 arc second diaphragm was used in the photometer for all observations. The three amplifiers were calibrated at the beginning and end of each observing session.

Data Reduction

The magnetic tape containing the data was fed to an IBM 1401 computer where the data were transformed from 7 track 200 BPI to 9 track 800 BPI format. This enabled the data to be fed into an IBM 370-65 computer which was used for most of the data reduction. Computer reductions consisted of printer plots of the raw data (star less sky) versus time for the entire night. In addition, intensity changes and system colors for flare events were calculated so that plots of intensity and color versus time and color-color plots could be made. These plots were also constructed with the use of the printer plot routines and later with the use of the Gould 5100 on-line plotter. The matching of the flare events to theoretical models was done with both the IBM 370-65 and a Hewlett Packard 9810A calculator.

CHAPTER III

THE OBSERVATIONS

The observing program consisted of the monitoring of four UV Ceti flare stars; YZ CMi, BD+16°2708, AD Leo, and EV Lac. A total of 44 observing runs were made, with the majority of time being spent on AD Leo and EV Lac. These two stars were emphasized because of their level of activity, apparent brightness, and accessibility from the latitude of the Rosemary Hill Observatory (+30°). The complete list of the monitoring times is presented in Appendix 1.

The effective wavelengths at which the observations were made were found by convolving the response curves of the apparatus (Figure 1) with the energy distribution of the star. The relation used was

$$\lambda_e = \frac{\lambda\, R(\lambda)\, S(\lambda)\, d\lambda}{R(\lambda)\, S(\lambda)\, d\lambda}$$

where

λ_e is the effective wavelength

$R(\lambda)$ is the ultraviolet, blue, or red response curve plotted in Figure 1,

and $S(\lambda)$ is the energy distribution of the star.

The energy distribution for a dM4.5 star (assumed for both

EV Lac and AD Leo) was obtained by linearly interpolating between the dM4 and dM5 energy distributions given in Straizys and Sviderskiene (1972). The resultant effective wavelengths were 3500, 4632, and 6496 Å for the ultraviolet, blue, and red bandpasses respectively.

Only brightness variations substantial enough to provide color data were reduced and noted as "flare activity." Though no strict criteria were applied to the strength of the events, activity treated as a flare typically exhibited a maximum in the uv bandpass at least three standard deviations above the quiet level of the star. The quiet levels and noise levels of the intensity of the star in the various bandpasses were found by obtaining the average value and standard deviation of a 2-to 3-minute segment of data immediately preceding the onset of the event.

A total of 107 hours 41 minutes was spent monitoring EV Lac and AD Leo, resulting in 15 major flares. No flare activity was observed on either YZ CMi or BD+16°2708. As mentioned above, some events were not reduced due to their small amplitudes. However, there were only about 6 of these events. Of the 15 major flares, several were obviously not isolated. In particular, the events observed on AD Leo on 26 February, 1974, and on EV Lac on 7 and 9 October, 1973 show several outbursts occuring within minutes of each other. Considering the typical time interval between flares for UV Ceti stars, it is highly unlikely that events could occur on the same star in such rapid succession and not be physically related in some way.

Tables 1a and 1b contain the parameters for the observed flare activity of EV Lac and AD Leo respectively. Column 1 contains the UT date of the event. Column 2 gives the name of the event by which it will be referred to hereafter. The initial number in the name indicates the day of the month on which the flare was observed. The following 2 letters give the month of the year. The final number is the last digit of the year. The final letter, if any, denotes the first (A), second (B), etc. event on the given date. For example, 90C3B refers to the second event observed on October 9, 1973. Column 3 gives the time of the maximum intensity of the flare. Column 4 lists the bandpass of the observations; and the integrated intensity, P, is given in units of minutes in column 5. P is defined to be $\int I_f(t)\, dt$, where I_f is the intensity of the flare light alone in terms of the quiet level of the star. Column 6 gives the maximum relative change in intensity of the star in terms of the quiet level (i.e. I_f max), column 7 the noise level of the signal in the same units, and column 8 the airmass at which the observations were made. This airmass was computed for the time of maximum light for the event.

EV Lac is a visual binary with the companion, significantly bluer than the variable, located about 5 arc seconds from the primary. Both components were included in the 24 arc second diaphragm used for the observations. However, measures of the individual components enable the parameters of the flare to be related to the variable only. The measures

Table 1a

OBSERVED PARAMETERS FOR FLARES OF EV LAC

Date	ID	UT of Max	Band	P(min)	I_f	σ	X
26 Aug 1973	26AU3	5 59 40	uv	3.24	1.50	0.31	1.034
			blue	0.35	0.12	0.03	
			red	0.16	0.07	0.02	
3 Sep 1973	3SE3	7 24 50	uv	3.80	1.78	0.35	1.129
			blue	0.12	0.17	0.04	
			red	0.14	0.07	0.02	
7 Oct 1973	70C3	2 04 41	uv	32.00	7.16	0.31	1.065
			red	1.40	0.26	0.01	
9 Oct 1973	90C3A	4 04 50	uv	3.04	3.51	0.35	1.057
			blue	1.14	1.25	0.04	
			red	0.16	0.49	0.02	
	90C3B	4 12 54	uv	17.10	2.08	0.35	1.064
			blue	1.30	0.18	0.04	
			red	0.60	0.09	0.02	
	90C3C	4 15 44	uv	*	3.98	0.35	1.066
			blue		0.45	0.04	
			red		0.16	0.02	
	90C3D	5 30 19	uv	6.25	6.47	0.46	1.182
			blue	0.58	0.65	0.04	
			red	0.24	0.23	0.02	
19 Aug 1974	19AU4	6 26 17	uv	1.33	1.27	0.21	1.034
			blue	0.14	0.18	0.06	
			red	0.01	0.05	0.01	
21 Sep 1974	21SE4	4 55 50	uv	6.04	6.06	0.15	1.044
			blue	0.66	0.78	0.05	
			red	0.20	0.11	0.01	

* The value of P given for 90C3B is the combined value for 90C3B and 90C3C, since the two events overlapped.

Table 1b

OBSERVED PARAMETERS FOR FLARES OF AD LEO

Date	ID	UT of Max	Band	P(min)	I_f	σ	X
21 Feb 1974	21FE4	5 07 12	uv	0.90	2.12	0.09	1.025
			blue	0.17	0.35	0.01	
			red	0.06	0.08	0.01	
26 Feb 1974	26FE4A	4 49 09	uv	72.40	8.65	0.12	1.024
			blue	8.60	1.50[a]	0.02	
			red	2.90	0.27	0.01	
	26FE4B	4 52 57	uv	b	9.51	0.12	1.022
			blue		1.69	0.02	
			red		0.31	0.01	
27 Feb 1974	27FE4	7 22 18	uv	1.34	1.00	0.13	1.142
			blue	0.22	0.14	0.01	
			red	0.02	0.03	0.01	
25 Apr 1974	25AP4	4 59 33	uv	1.18	1.45	0.15	1.452
			blue	0.10	0.24	0.02	
			red	0.01	0.04	0.01	
18 Apr 1975	18AP5	2 40 52	uv	1.03	0.85	0.06	1.023
			blue	0.21	0.14	0.02	
			red	0.07	0.05	0.01	

[a] The value of I_f in the blue band is estimated due to saturation of the amplifier before the gain could be changed.

[b] The value of P given for 26FE4A is the combined value for 26FE4A and 26FE4B, since the two events overlapped.

were obtained by placing the binary close enough to the edge of the diaphragm to exclude one of the components. Readings were taken first with one star excluded then the other. The brighter component of the system is known to be the flare star, so its brightness relative to the entire flux of the system could be computed. The measures indicated that the variable is responsible for 51, 77, and 87 per cent of the total flux of the system in the ultraviolet, blue, and red bandpasses respectively. Using these values, the observed intensities of the events and the noise levels quoted in Table 1a are relative to the flux of the variable component of the system only.

Figures 4 through 16 show the three-color light curves for the observed events except for Figure 6, a plot of event 70C3 which was observed in only 2 colors. A tabulation of the observed changes in intensity for all events is given in Appendix 2. For events tabulated for EV Lac, the listed changes in intensity are relative to the total light of the system.

For all events the relative change in the brightness of the star increased toward shorter wavelengths. It is interesting to note that in many cases, the greatest change in brightness relative to the noise level occured in the blue bandpass. That is, for these flares, the peak intensity in the blue rose above the quiet level of the star by a greater number of standard deviations than in the other bands. This is not surprising if, as suggested by Kunkel (1973),

the measurement of the "quiet" level of the star in the ultraviolet is constantly polluted with contributions from "microflare" activity, thereby causing the signal to seem noisier than if the star were really quiet between major flare activity. In most cases the red band is relativly insensitive to flare activity, and so does not show this microflaring disturbance of the quiet intensity.

Figure 4 - Three-color light curve for event 26AU3.

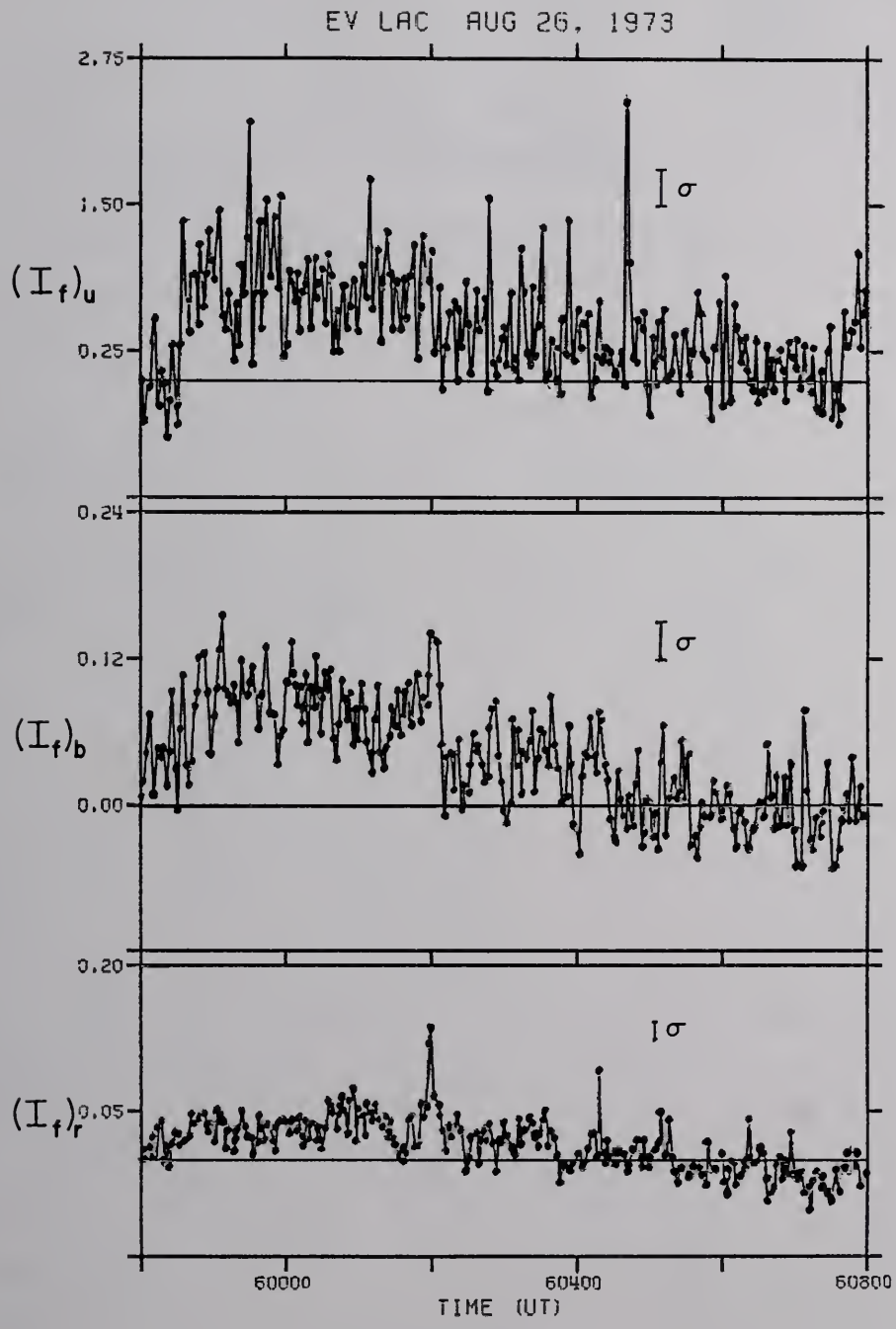

EV LAC AUG 26, 1973
2.75
1.50
0.25
$(I_f)_u$
1σ
0.24
0.12
0.00
$(I_f)_b$
1σ
0.20
0.05
$(I_f)_r$
1σ
60000
60400
60800
TIME (UT)

Figure 5 - Three-color light curve for event 3SE3.

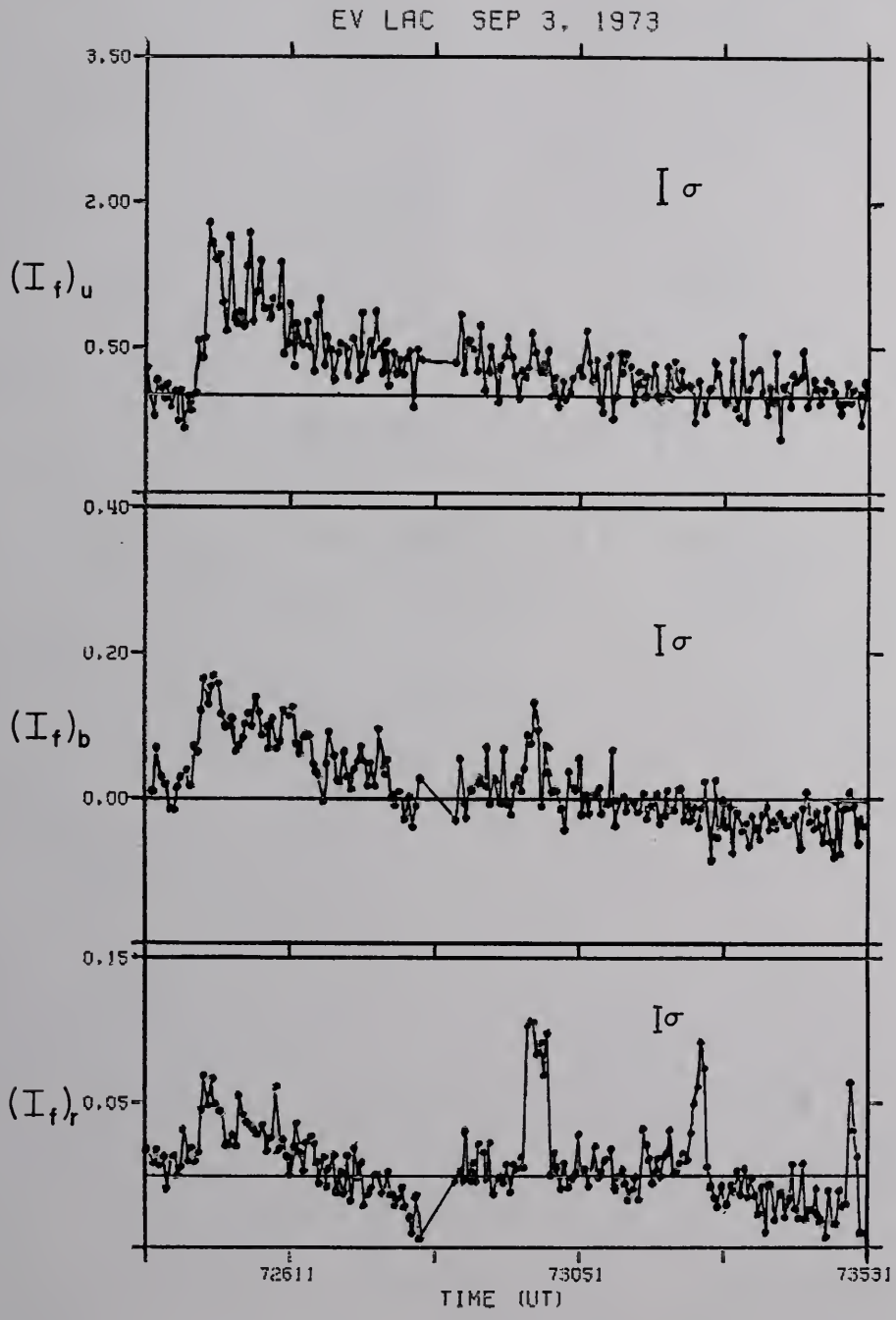

EV LAC SEP 3, 1973
3.50
2.00
0.50
$(I_f)_u$
Iσ
0.40
0.20
0.00
$(I_f)_b$
Iσ
0.15
0.05
$(I_f)_r$
Iσ
72611
73051
73531
TIME (UT)

Figure 6 - Two-color light curve for event 7003.

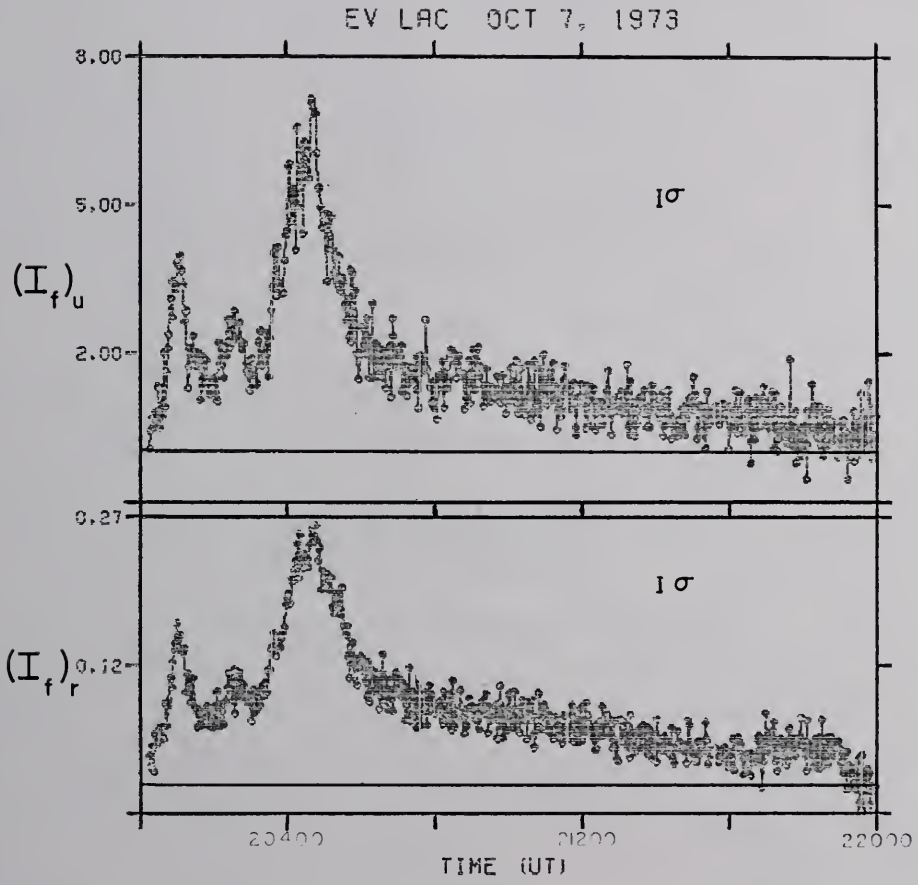

EV LAC OCT 7, 1973
8.00
5.00
2.00
$(I_f)_u$
1σ
0.27
0.12
$(I_f)_r$
1 σ
20400
21200
22000
TIME (UT)

Figure 7 - Three-color light curve for event 90C3A.

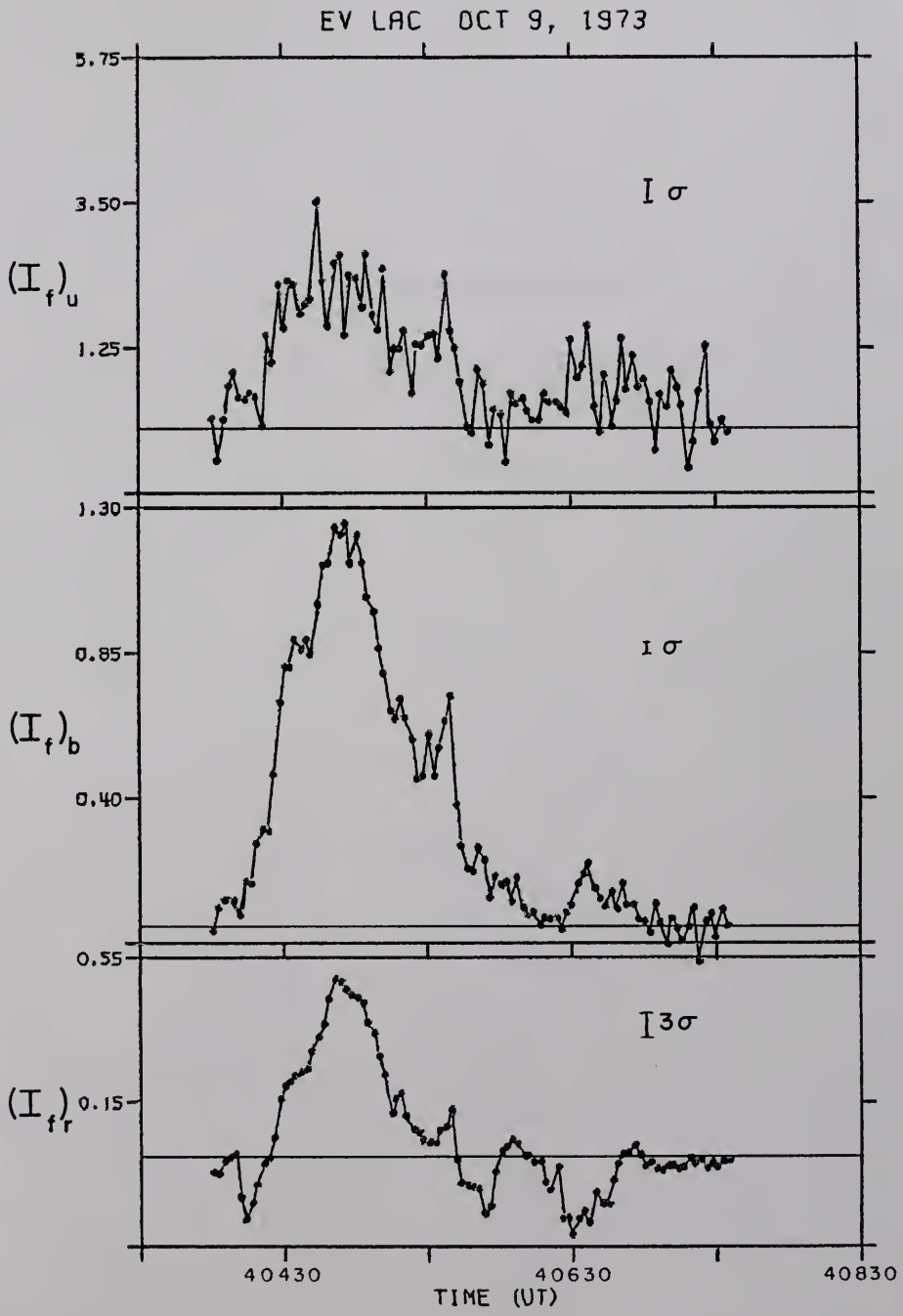

EV LAC OCT 9, 1973
5.75
3.50
1.25
$(I_f)_u$
1σ
1.30
0.85
0.40
$(I_f)_b$
1σ
0.55
0.15
$(I_f)_r$
3σ
40430
40630
40830
TIME (UT)

Figure 8 - Three-color light curve for events 90C3B,C.

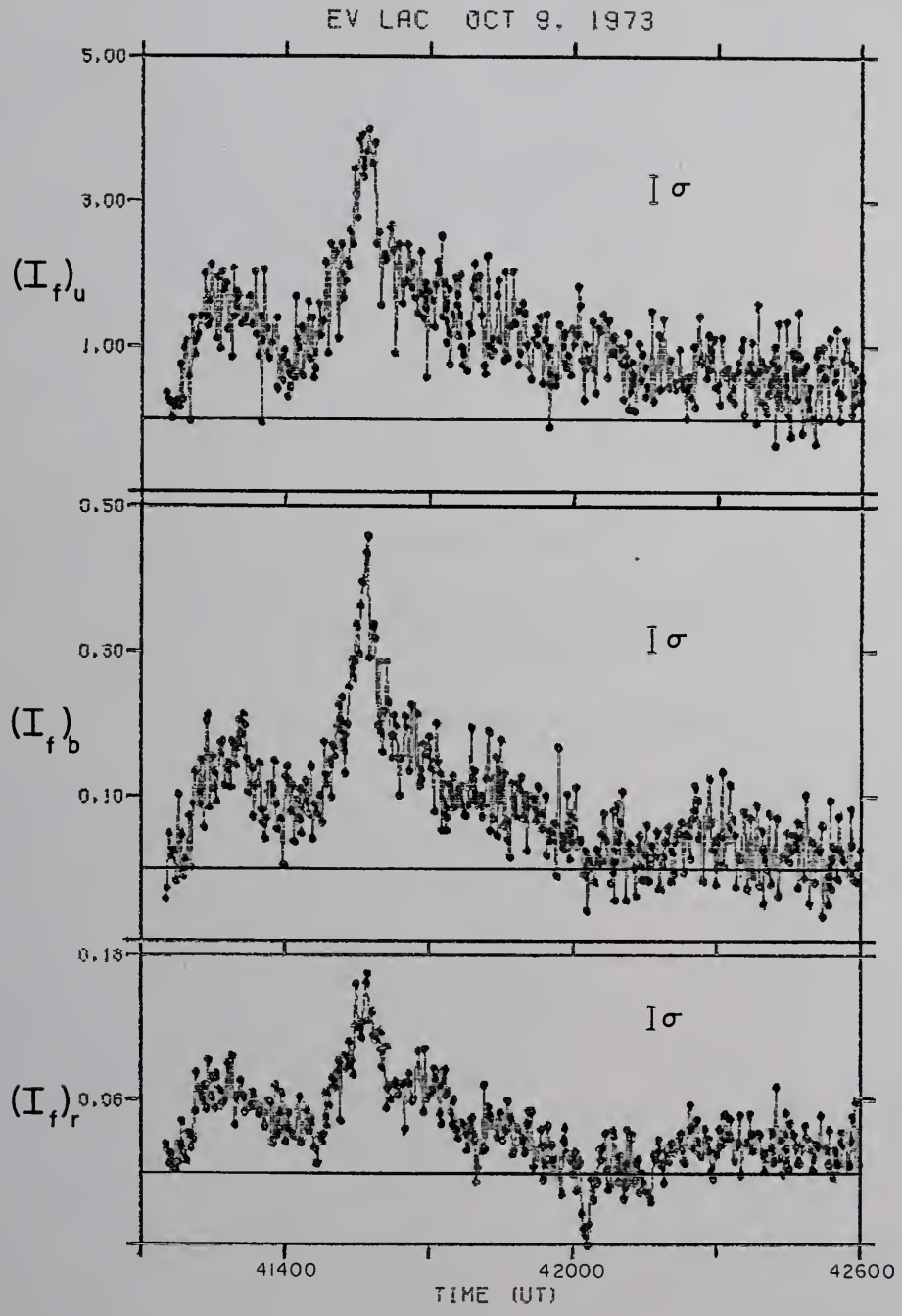

EV LAC OCT 9, 1973
5.00
3.00
1.00
$(I_f)_u$
1σ
0.50
0.30
0.10
$(I_f)_b$
1σ
0.18
0.06
$(I_f)_r$
1σ
41400
42000
42600
TIME (UT)

Figure 9 - Three-color light curve for event 90C3D.

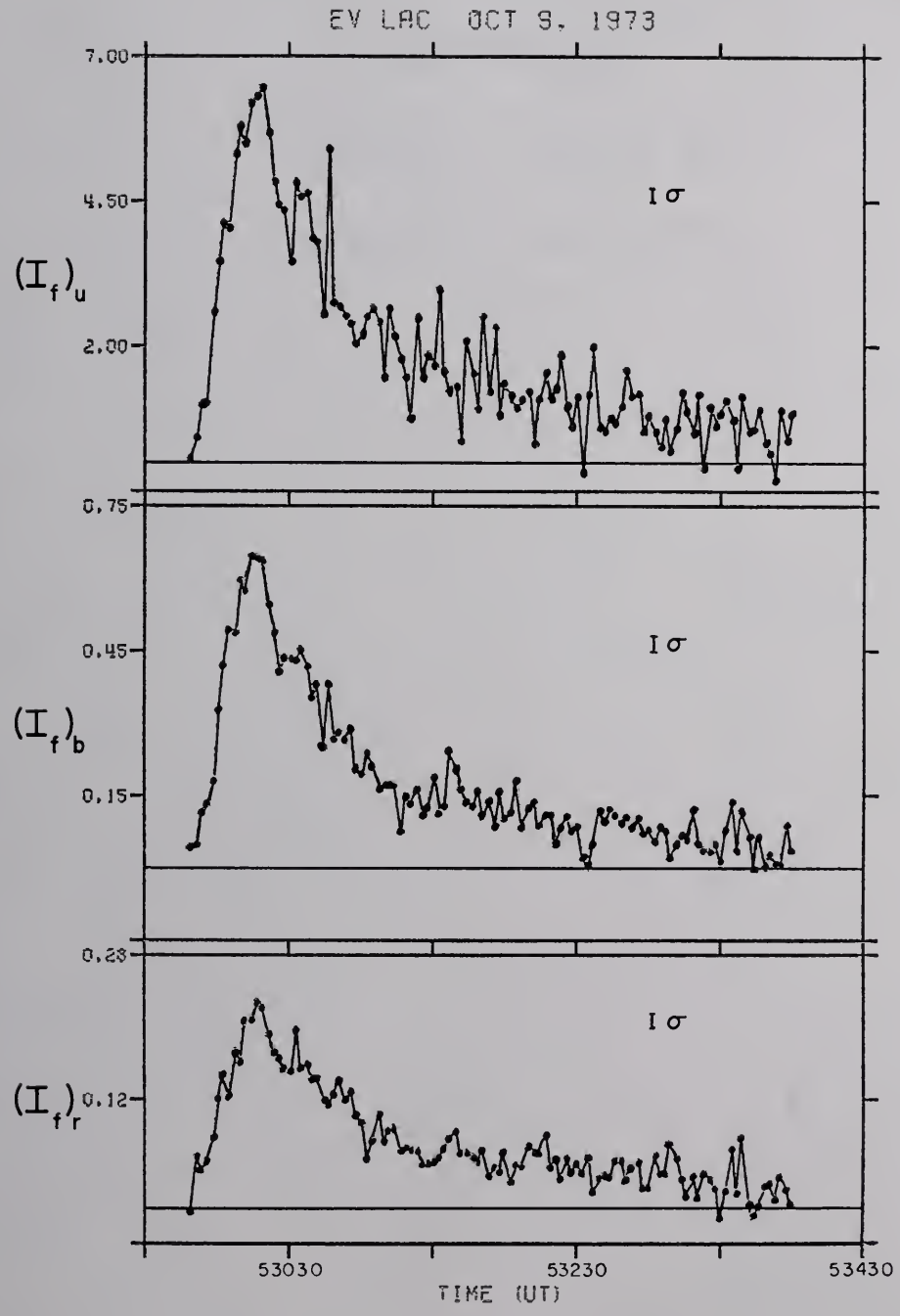

EV LAC OCT 9, 1973
7.00
4.50
2.00
$(I_f)_u$
1σ
0.75
0.45
0.15
$(I_f)_b$
1σ
0.28
0.12
$(I_f)_r$
1σ
53030
53230
53430
TIME (UT)

Figure 10 - Three-color light curve for event 19AU4.

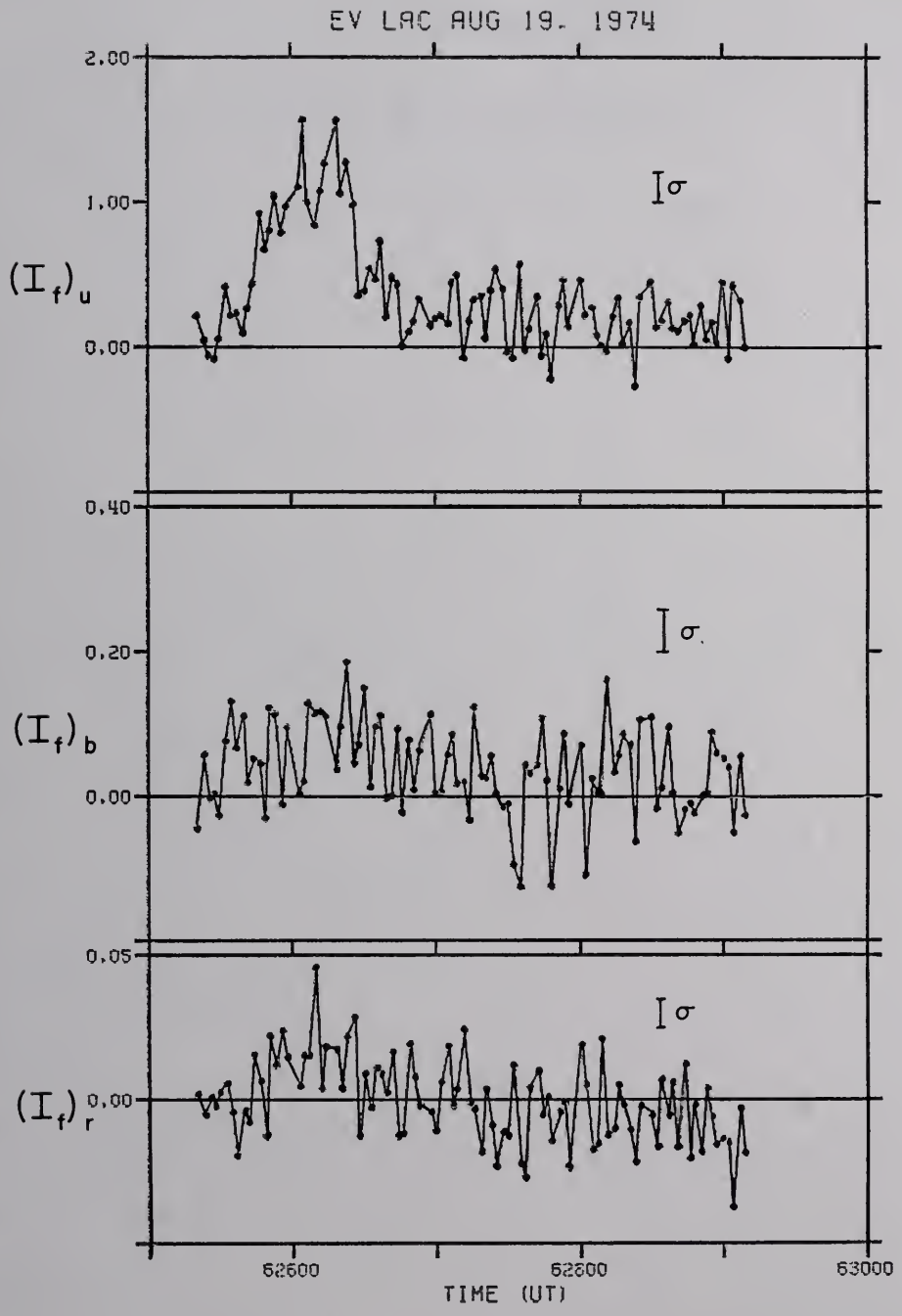

EV LAC AUG 19. 1974
2.00
1.00
0.00
$(I_f)_u$
Iσ
0.40
0.20
0.00
$(I_f)_b$
Iσ
0.05
0.00
$(I_f)_r$
Iσ
62600
62800
63000
TIME (UT)

Figure 11 - Three-color light curve for event 21SE4.

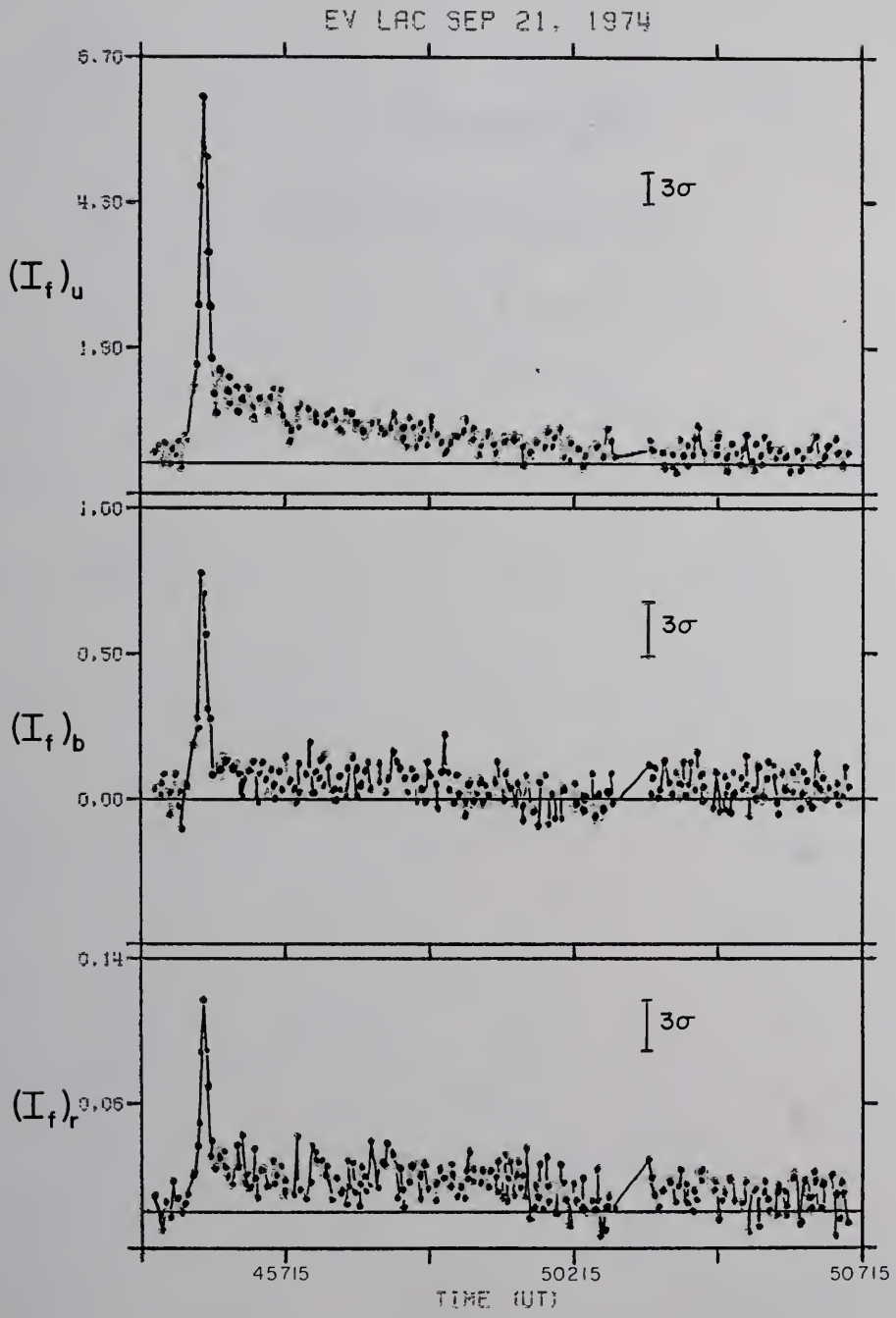

EV LAC SEP 21, 1974
6.70
4.30
1.90
3σ
$(I_f)_u$
1.00
0.50
0.00
3σ
$(I_f)_b$
0.14
0.06
3σ
$(I_f)_r$
45715
50215
50715
TIME (UT)

Figure 12 - Three-color light curve for event 21FE4.

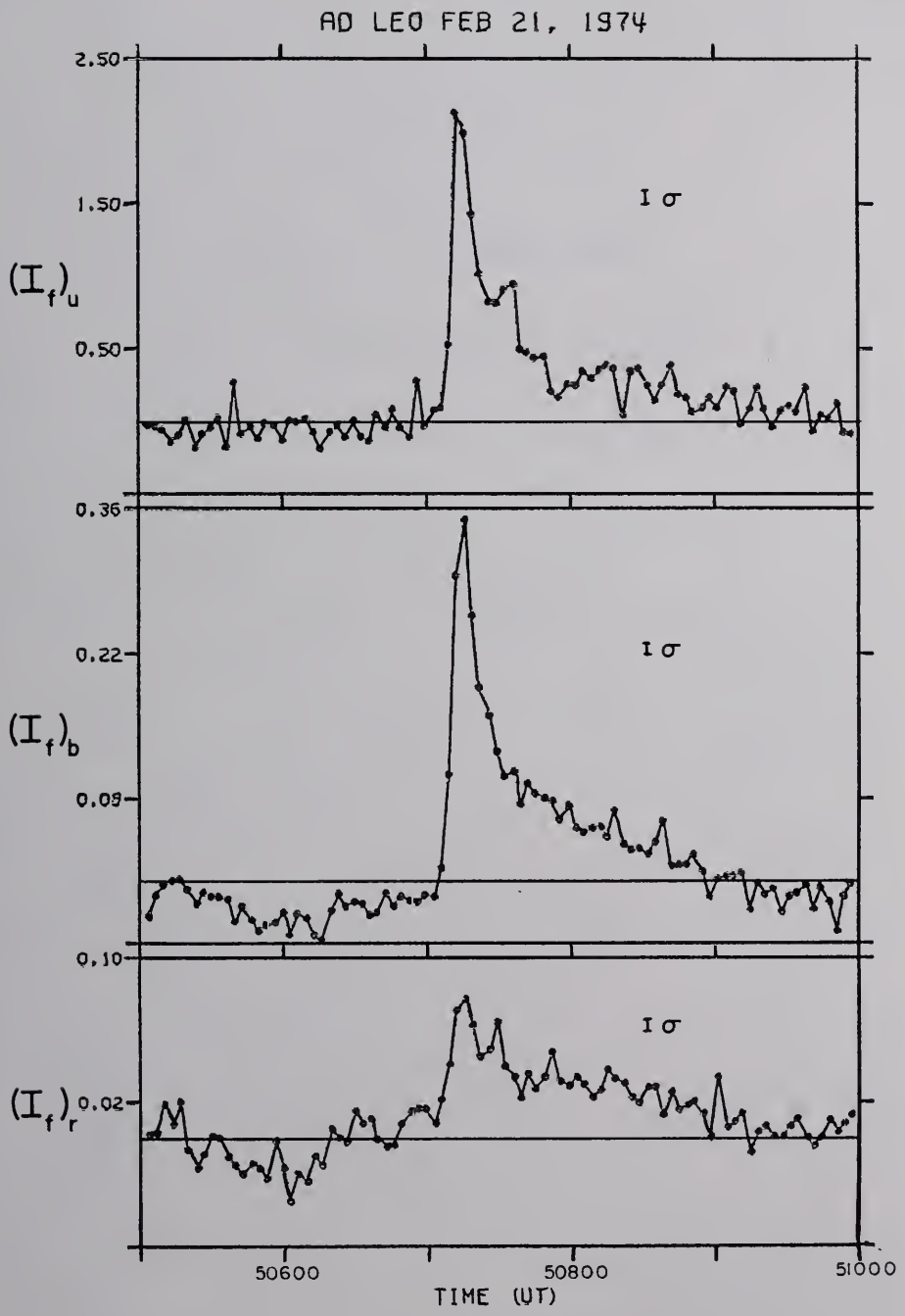

AD LEO FEB 21, 1974
2.50
1.50
0.50
$(I_f)_u$
1σ
0.36
0.22
0.09
$(I_f)_b$
1σ
0.10
0.02
$(I_f)_r$
1σ
50600
50800
51000
TIME (UT)

Figure 13 - Three-color light curve for events 26FE4A,B.

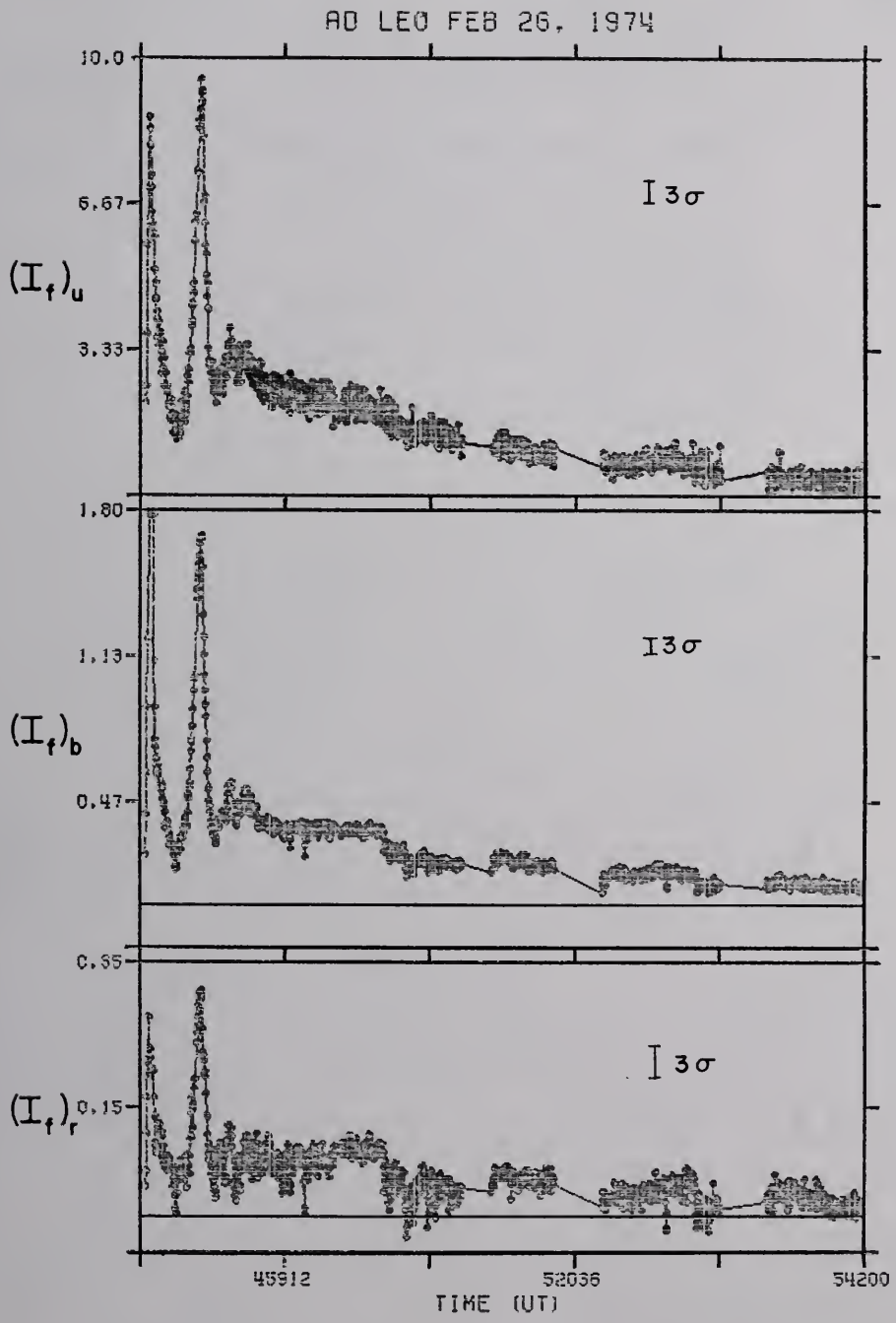

AD LEO FEB 26, 1974
10.0
6.67
3.33
$(I_f)_u$
I 3σ
1.80
1.13
0.47
$(I_f)_b$
I 3σ
0.65
0.15
$(I_f)_r$
I 3σ
45912
52036
54200
TIME (UT)

Figure 14 - Three-color light curve for event 27FE4.

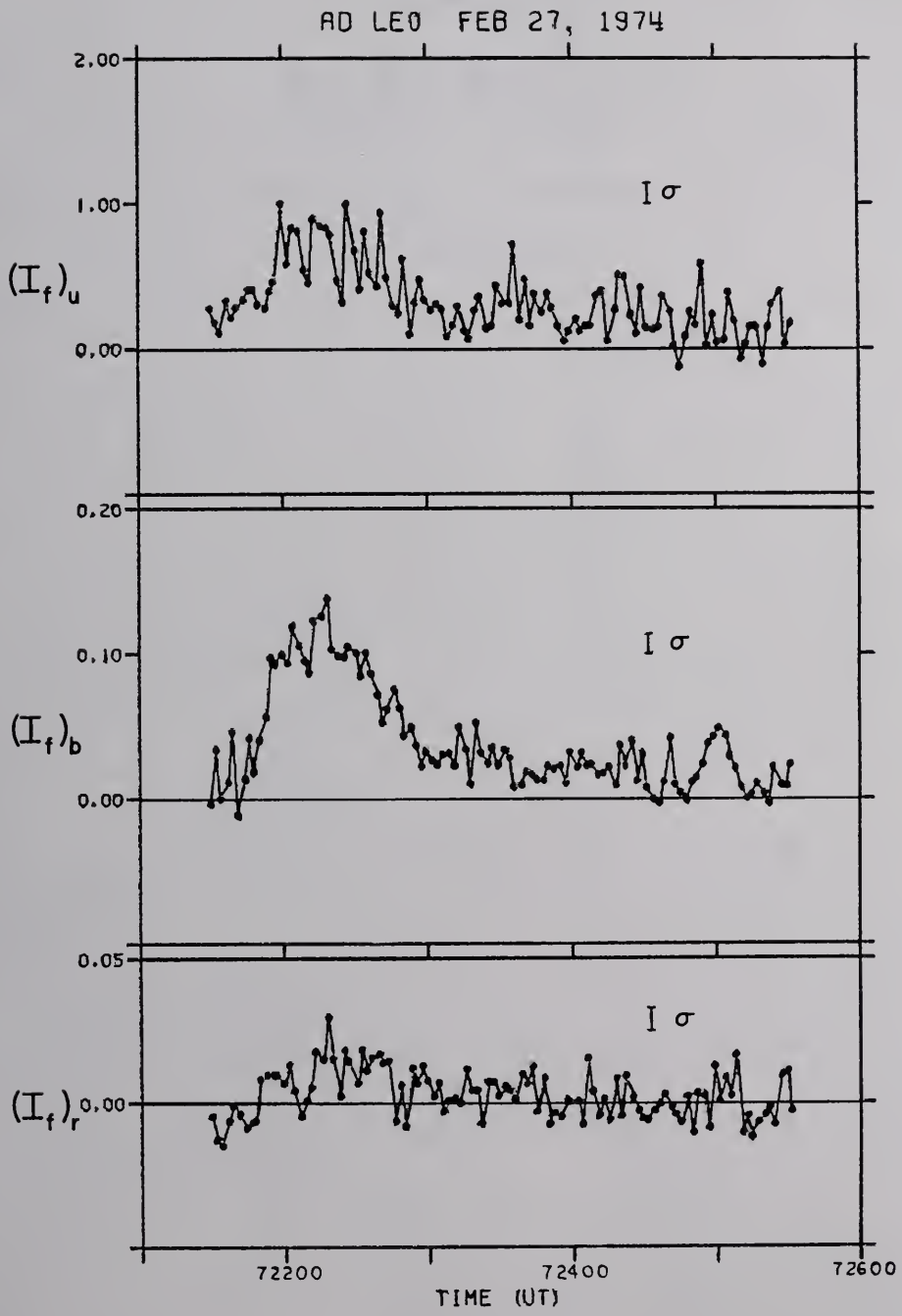

AD LEO FEB 27, 1974
2.00
1.00
0.00
$(I_f)_u$
I σ
0.20
0.10
0.00
$(I_f)_b$
I σ
0.05
0.00
$(I_f)_r$
I σ
72200
72400
72600
TIME (UT)

Figure 15 - Three-color light curve for event 25AP4.

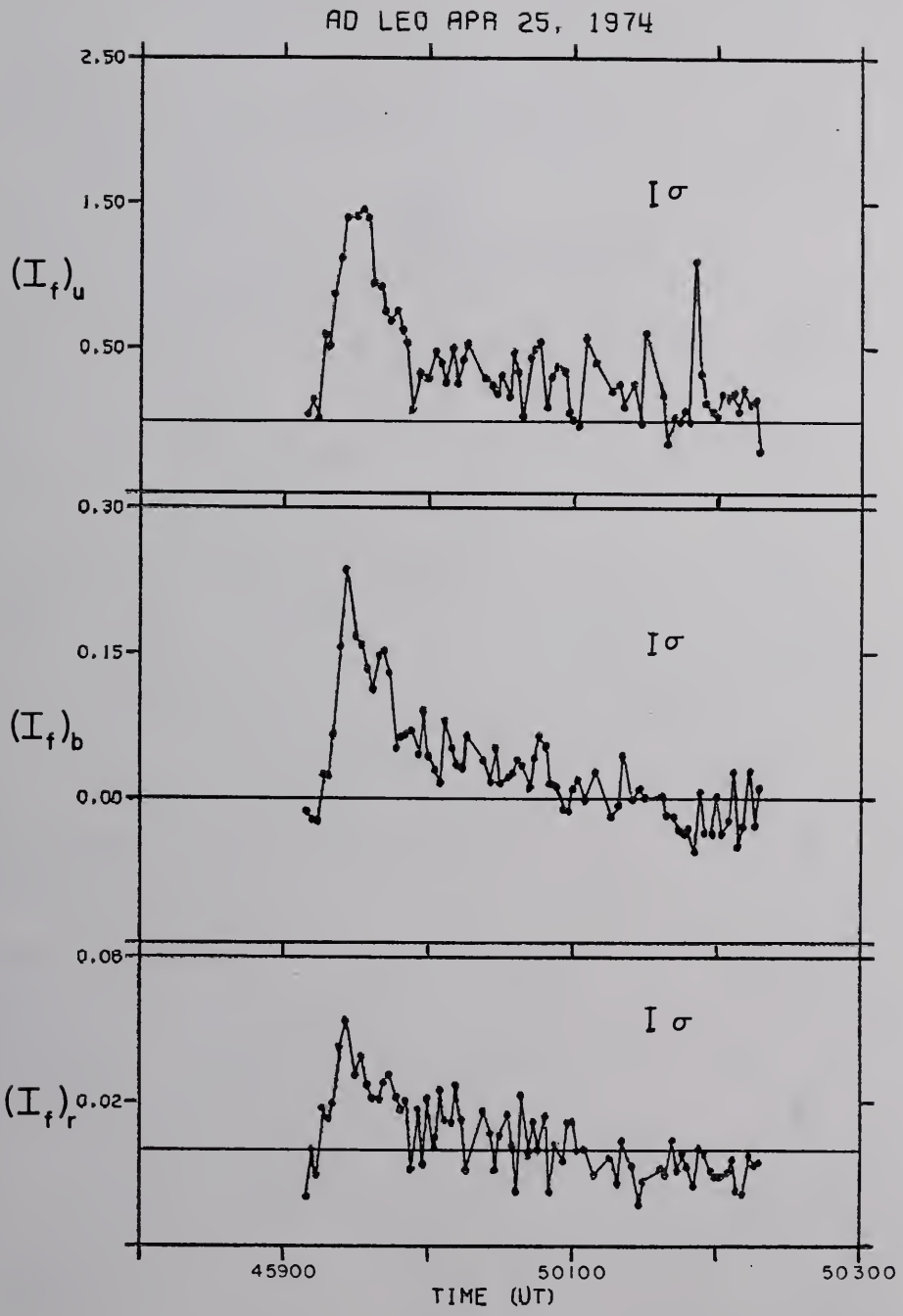
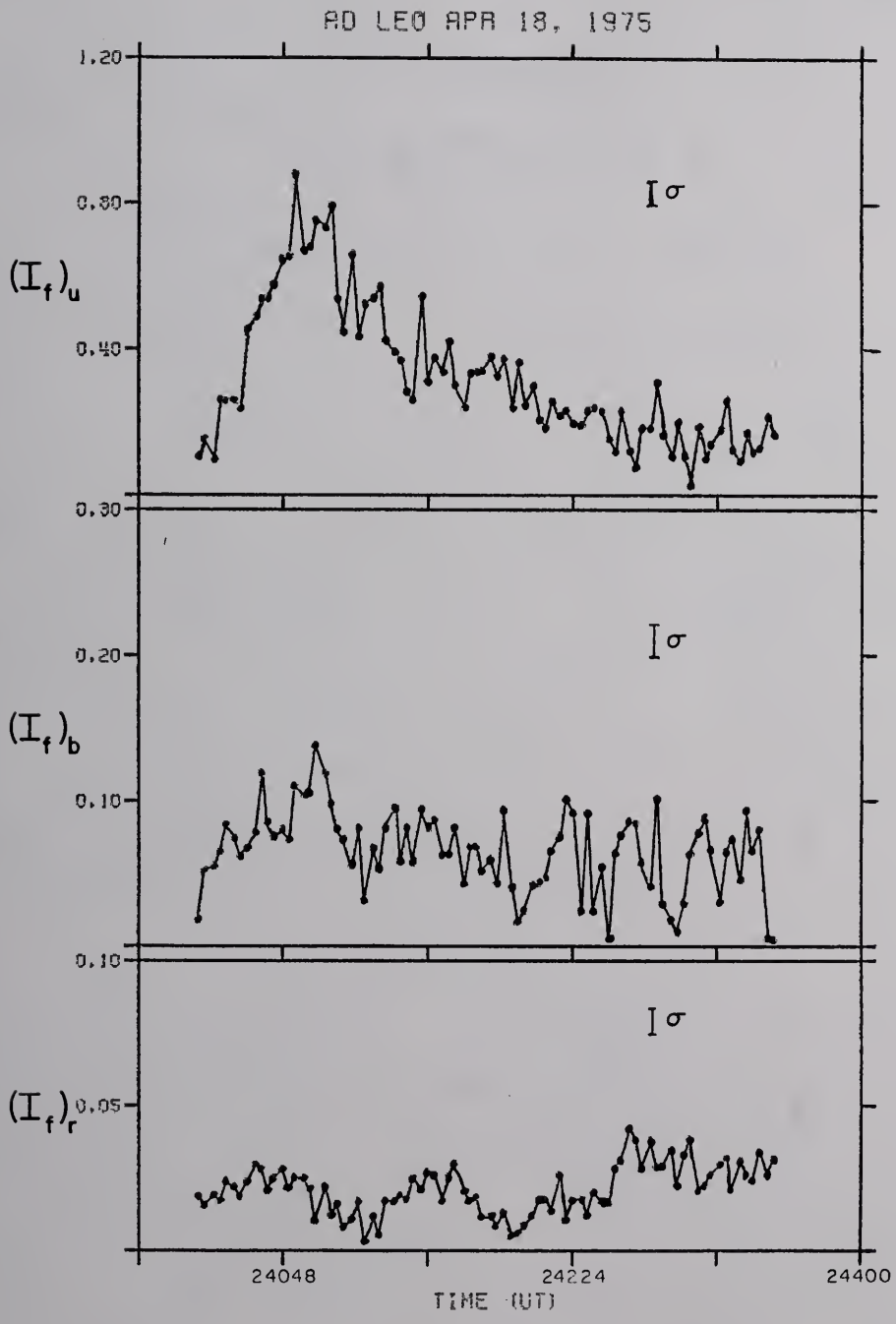

AD LEO APR 25, 1974
2.50
1.50
0.50
$(I_f)_u$
Iσ
0.30
0.15
0.00
$(I_f)_b$
Iσ
0.08
0.02
$(I_f)_r$
Iσ
45900
50100
50300
TIME (UT)

Figure 16 - Three-color light curve for event 18AP5.


AD LEO APR 18, 1975
1.20
0.80
0.40
$(I_f)_u$
Iσ
0.30
0.20
0.10
$(I_f)_b$
Iσ
0.10
0.05
$(I_f)_r$
Iσ
24048
24224
24400
TIME (UT)

CHAPTER IV

THEORETICAL CONSIDERATIONS

Like most other discoveries in science, the rapid increase in the brightness of certain red dwarf stars has stimulated a large number of possible explanations. Everything from Hertzsprung's asteroid hypothesis to the involvement of starspots and intense magnetic fields have been or are now being used to try and explain the outbursts (see Gershberg 1970 for summary of theories.)

The Nebular Model

The nebular model of Gershberg (1968) and Kunkel (1967; 1970) poses problems for the direct analytic application of observed data to the theory. The model represents flare light as recombination radiation from an isothermally expanding cloud of ionized hydrogen. The light curve is given by

$$\frac{I(t)}{I_{max}} = \frac{Q^K}{\left\{Q^K + \left(\frac{A}{B(K-1)}\right)\left(Q^K - Q\right)\right\}^2}$$

where

$Q = 1 + \frac{t}{A}$, t being measured from time of maximum light;

$A = R/v$ = the expansion time scale of a cloud with an initial radius, R, expanding with a velocity, v;

B = the characteristic time scale of recombination as a function of the electron density and temperature;

and K = 1, 2, or 3 for the different geometries of expansion.

There are serious problems encountered in attempting to apply data to the equation since the problem is overdetermined. The unknown quantities A, B, and K cannot be solved for analytically. In the past, the theory has been fitted to observed light curves by choosing values for the unknowns and matching the resulting curves with the observations by trial and error. Unfortunately, the light curves produced by the theory are not independent of each other. For example, the family of curves produced by varying K and keeping A and B constant can be closely approximated by holding K constant and varying A or B. Obviously, this provides little in the way of practical insight into the flare phenomenon.

The theory itself has been losing favor recently as more and better observations have become available. For these reasons, the nebular model will not be quantitatively treated here.

Fast Electron Model

The fast electron model proposed by Gurzadyan explains flare light as the result of inverse Compton scattering of infrared photons by a cloud of electrons having energies that are suprathermal but not relativistic. The energies of the electrons are assumed to be identical and in the range of $10^6 - 10^7$ eV. If $\mu = E/m_o c^2$ = the energy of the fast electron

in terms of its rest energy, Gurzadyan finds that the photon scattered from a fast electron will have its frequency increased by a factor of μ^2. That is, it will become bluer. So, the appearance of a cloud of fast electrons above the surface of the star is accompanied by a sudden increase in the radiation originating in the blue end of the spectrum. The theory also predicts that an increase in intensity at the blue end of the spectrum will be accompanied by a decrease in the intensity beyond about 7000Å (the exact wavelength depends on the temperature and the electron energy). This results since, presumably, these are the photons which undergo the inverse Compton scattering. The number density of the electrons reaches a maximum at flare maximum and then begins to diminish. This decrease in the optical depth of the cloud causes the decrease in flare light. The origin of the cloud of electrons is unknown.

Several points need to be kept in mind with regard to the fitting of data to the theory. First, as it is used in the theory, optical depth is a measure of the number density of electrons; and, as such, it is wavelength-independent. This means that the value for the optical depth at any time during a flare should be identical in all three colors. Secondly, the theory predicts a constant color for the flare light. This is implied in the form of the expression for the decay in the optical depth. According to the theory, the optical depth, τ, is represented by

$$\tau = \tau_o (t_r/t)^n \qquad (1)$$

where

τ_o = the maximum value of the optical depth,

t = the time elapsed since maximum light,

t_r = the rise time of the flare,

and n = a dimensionless quantity which indicates the number of dimensions in which the cloud is expanding as it dissipates.

A spherical expansion is denoted as $n = 2$. If $1 < n < 2$, the expansion is like a slab which is increasing in thickness. The theory states that n is also wavelength independent. Thus, two of the most important points to look for are whether or not τ_o and n are identical for all three colors.

The light curve of a flare is represented by the fast electron theory according to the equation,

$$I_f = (1 + A\tau)e^{-\tau} - 1 \qquad (2)$$
$$= \Delta I / I_o$$

where

$$A = A(\mu, T, \lambda)$$
$$= \frac{1}{4\pi\mu^4} \frac{\exp(C_2/\lambda T) - 1}{\exp(C_2/\mu^2\lambda T) - 1}, \qquad (3)$$

$C_2 = hc/k = 1.439$ cm · K,

μ = the electron energy as mentioned above,

and τ = the instananeous value of the optical depth of the electron cloud as given in equation (1).

The parameters solved for from the data are τ_o and n. All others are known. The value of t_r is gotten from the light curve, λ is the effective wavelength of the photoelectric bandpass, and T is the temperature of the star.

At flare maximum, $\tau = \tau_o$, and

$$I_f = (1 + A\tau_o)e^{-\tau_o} - 1$$

For a given value of A, the largest possible I_f that the theory predicts is obtained by setting

$$\frac{\partial I_f}{\partial \tau} = 0 = -e^{-\tau} + Ae^{-\tau} - A\tau e^{-\tau}$$

This reduces to $\tau_{max} = 1 - \frac{1}{A}$ (4)

This represents the optical depth of the electron cloud at which the maximum possible value of I_f in a given bandpass is attained. In other words, for a given A, all flare events observed on the star must have maxima that are less than or equal to the value of I_f when equation (4) is substituted into equation (2). Thus, the value of the maximum for a flare is related to the temperature, T, of the star and the energy of the electron cloud. If $\tau > \tau_{max}$, the cloud will absorb sufficient radiation from the photosphere so that the observed I_f will be less than the maximum I_f possible. Since A is always positive, $\tau_{max} < 1$, and from physical considerations, τ must be greater than zero for an increase in intensity to occur. Table 2 gives the values for A and the maximum allowable values of I_f for various values of T and the electron energy. The wavelengths used were the effective wavelengths of the three-channel photometer (3500, 4632, and 6496Å). Columns 6-8 are the maximum possible values of I_f at the three effective wavelengths. Note that for $\mu^2 = 10$ and T = 3100 K, A(r)<1. This means that $\tau_{max} < 0$. It follows that at this

Table 2

THEORETICAL PARAMETERS AND MAXIMUM FLARE AMPLITUDES FOR FAST ELECTRON THEORY*

T(K)	μ^2	A(u)	A(b)	A(r)	u	b	r
3100	5	138.839	11.558	1.271	50.4	3.6	.027
	10	165.460	10.386	0.967	60.2	3.2	
3000	5	196.486	14.428	1.516	71.7	4.7	.079
	10	242.524	13.767	1.172	88.6	4.4	.012
2900	5	284.990	19.010	1.832	104.	6.4	.163
	10	365.340	18.626	1.441	134.	6.2	.061
2800	2	30.728	5.125	1.059	10.7	1.3	.002
	5	424.765	25.567	2.246	156.	8.8	.290
	10	567.288	25.778	1.800	208.	8.9	.154
	20	437.348	17.667	1.118	160.	5.9	.006
2700	5	652.526	35.180	2.798	239.	12.3	.472
	10	911.061	36.589	2.288	335.	12.8	.303
2600	5	1036.790	49.657	3.549	381.	17.6	.731
	10	1519.250	53.420	2.968	558.	19.0	.529

* Tabulated amplitudes are in intensity units.

temperature, an increase in intensity is impossible at $\lambda = 6496\text{Å}$; so a flare on this star (if $\mu^2 = 10$) would produce a decrease in the intensity of the star in the r band.

Several characteristics of the theory can be found from an investigation of the table and equations (1) and (2).

(A) For a given temperature, the larger the value of A, the faster the light curve will decay. In this case, the parameter n in the optical depth equation decreases.

(B) For a given value of μ^2, the lower the temperature, the smaller is n.

(C) For given values of μ^2 and T, an increase in n makes the curve decay faster.

(D) The larger the temperature, the smaller are the possible flare amplitudes for the same values of μ^2.

Fitting the Observed Light Curves

The procedure used to fit the light curves was the following. The rise time, t_r, was obtained from the light curve directly, as was the maximum value of I_f. Through his matching of observed light curves, Gurzadyan (1970) found that $\mu^2 = 10$ is the best value for the electron energy. The temperature was assumed to be 2800 K for both EV Lac and AD Leo. This along with the effective wavelength of a bandpass defines a value of A. At maximum, $\tau = \tau_o$, so

$$I_f = (1 + A\tau_o)e^{-\tau_o} - 1.$$

I_f at maximum is obtained from the light curve and τ_o is found by iteration using Newton's iterative procedure for finding roots. The value of τ_o is analytically found in this way and is the exact value consistent with the theory. The approximation used by Gyrzadyan (1969) was not used even for $\tau \ll 1$. After maximum, equation (2) is iterated using the observed values of I_f to find a series of values for $\tau(t)$. Each value of $\tau(t)$ is assumed to depend on τ_o according to equation (1), so n can then be calculated by,

$$n = \frac{\ln(\tau/\tau_o)}{\ln(t_r/t)} \qquad (5)$$

This procedure gives values of τ and n for each observation. The values obtained for n were then averaged to get a value with which to describe the entire curve. A curve can then be plotted from the substitution of the value for τ_o and n into equation (2).

When this procedure was used on the data, it was found that the values $\mu^2 = 10$ and T = 2800 K could not be used to describe all of the observed light curves. Comparison of Tables 1 and 2 shows that flares 70C3, 90C3A,C,D, and 26FE4A,B all have I_f maxima that can be fitted in the u and b bands, but are too large in the r band. The theory was not applied to 90C3A because of its obviously anomalous character. There are at least three possible explanations for the large amplitude in the red bandpass. Either μ^2 had to be decreased, T had to be decreased, or the excess radiation in the r band was due to Hα emission strong enough to affect the total flux

in the band to the extent that it was too great for $\mu^2 = 10$ and T = 2800 K. The theory does not treat line emission. However, these stars show emission lines in their quiet spectrum, and the lines are greatly enhanced during a flare. The effective wavelength of the red bandpass lies close to the Hα line, so excess line emission is a possible explanation. From the convolution of the response curve of the r bandpass with the energy distribution of the quiet photosphere, it was found that approximately 1.1 per cent of the total signal in the r band for the quiet level of the star is due to Hα emission. For the theory to be applied to the data, the excess radiation must be subtracted out of the total observed I_f. A value for ΔHα could be arrived at if the change in the intensity of the continuum could be estimated. Since τ_o should be the same for all wavelengths, the τ_o found from the uv and b curves could be used in equation (2) to give $I_f$max for the r band. This then could be used to find the ΔHα from

$$\Delta H\alpha = \frac{\Delta I_{obs} - 0.989\Delta I_c}{0.011}$$

where ΔI_c is the value of I_f max in the r band found by substituting the value of τ_o into equation (2). ΔI_{obs} is the observed maximum value of I_f. The constants 0.989 and 0.011 result from the convolution procedure mentioned above. However, there is a problem with this procedure, since, as will be discussed later, the values of τ_o were not as predicted by the theory. In fact, τ_o for the uv band was typically an order of magnitude smaller than in the r band.

So the value of τ_o could not be estimated for the r band by this method. The other possibility is to assume the ΔI_c was the maximum allowed (i.e. 0.154) and attribute the excess to the change in the strength of Hα. This procedure leads to values of ΔHα at maximum of 9.8, 30.7, 1.5, 11.0, 21.6, and 14.3 for the 6 events mentioned above. These results are obviously subject to large uncertainties and are listed here only as possible considerations.

The first procedure used in this study for flares which showed too large an increase in r was to change the value of μ^2 while keeping T at 2800 K. As can be seen from Table 2, μ^2 is reduced to allow for larger amplitudes in I_f. Reducing μ^2 to 5 allowed all the events to be fitted except for 26FE4B (and 90C3A which was not fitted as, mentioned above). It was discovered that for T = 2800 K, there existed no value of A large enough to allow a value of I_f great enough to fit the observed maximum in the red bandpass for event 26FE4B. The second procedure was to force μ^2 to equal 10 and vary T in steps of 100 K until the flare light curve could be fitted. Except for 26FE4B, this necessitated only a decrease in T of 100 K. For 26FE4B, T had to be reduced to 2600 K. As is obvious from Table 2, if a flare could be fitted with μ^2 = 10 and T = 2800 K, it could also be fitted with a lower temperature. In these cases, only the first fit was made. The final values for the parameters are given in Tables 3 and 4. Table 3 lists the parameters for the temperature of 2800 K. Table 4 contains the values of the parameters when T was

Table 3

TABULATION OF THE FITTED PARAMETERS IN THE FAST ELECTRON THEORY FOR A TEMPERATURE OF 2800 K

Event	μ^2	Band	n	τ_0	t_r(sec)
70C3	5	uv	1.50	.0172	118
		red	1.50	.3542	
90C3C	5	uv	1.46	.0095	104
		blue	2.17	.0190	
		red	2.23	.1689	
90C3D	5	uv	1.09	.0155	23
		blue	1.14	.0266	
		red	1.24	.2729	
21FE4	10	uv	1.03	.0038	9
		blue	1.04	.0143	
		red	0.62	.1170	
26FE4A	5	uv	0.73	.0208	16
		blue	0.80	.0653	
		red	0.97	.3895	
25AP4	10	uv	0.83	.0026	9
		blue	0.98	.0098	
		red	0.89	.0547	
21SE4	10	uv	1.00	.0108	17
		blue	1.13	.0323	
		red	1.00	.2098	

Table 4

TABULATION OF THE FITTED PARAMETERS IN THE FAST ELECTRON THEORY FOR $\mu^2 = 10$

Event	T(K)	Band	n	τ_0	t_r(sec)
70C3	2700	uv	1.50	.0079	118
		red	1.50	.3255	
90C3C	2700	uv	1.30	.0044	104
		blue	1.90	.0131	
		red	2.03	.0612	
90C3D	2700	uv	1.10	.0072	28
		blue	1.18	.0182	
		red	1.23	.2568	
21FE4	2800	uv	1.03	.0038	9
		blue	1.04	.0143	
		red	0.62	.1170	
26FE4A	2700	uv	0.72	.0096	16
		blue	0.79	.0441	
		red	0.93	.3529	
26FE4B	2600	uv	0.93	.0063	104
		blue	1.05	.0333	
		red	1.11	.2050	
25AP4	2800	uv	0.83	.0026	9
		blue	0.98	.0098	
		red	0.89	.0547	
21SE4	2800	uv	1.00	.0108	17
		blue	1.13	.0323	
		red	1.00	.2098	

allowed to vary. An examination of the table shows that no one temperature could be used with $\mu^2 = 10$ to produce a satisfactory fit to the light curves. A temperature of 2700 K fits all the events except 26FE4B, for which T had to be 2600 K. The photospheres of these stars are not believed to show overall variations in temperature, so another explanation must be found for the discrepancies in T that seem to be present in Table 4. A possible explanation stems from the studies in recent years of the slow semiperiodic variations in these and other stars. The mechanism invoked to explain these low-amplitude variations in brightness is, as mentioned in Chapter 1, the existence of spots on the surface of the stars. It has been suggested (Mullan 1973; 1974) that the sizes of the spots are proportional to the depth of the convective zone in the star. If this is true, flare stars should exhibit the most pronounced spot activity, since M stars are the most convective of all spectral classes. Assuming that the spot region is facing the earth at the time of a flare, the difference in temperatures in Table 4 may be explained by the existence of these spots on the star. Assuming the stellar and spot energy distributions to be blackbody, if a spot is visible on the surface of the star and a Planck curve is fitted to the observed flux distribution, the effective temperature arrived at would be less than that of the actual photospheric temperature. In particular, if ψ represents the flux per unit area of a blackbody at a certain wavelength and temperature,

$$\psi_p (1 - S) + \psi_s \cdot S = \psi_{ps} \qquad (6)$$

where

ψ_p is the flux as defined above for the true photospheric temperature of the star,

ψ_s is the flux from a blackbody at the temperature of the spot,

ψ_{ps} represents the fitted curve to the combined effects of the photosphere and spot for the "observed" temperature,

and S is the fraction of the visible disk of the star occupied by the spot region.

The visible disk of the star is here taken to have an area of 1. This equation was used substituting 6496Å for the wavelength in the Planck equations. The temperature of the star was assumed to be 2800 K in order to get ψ_p. A temperature can be assumed for the spot so that ψ_s can be calculated and S can be found by substituting a temperature for the combined photosphere + spot observed flux. Mullan (1974) found that spots on YY Geminorum could take up 19 per cent of the total surface area of the star and have temperatures of from 1590-1890 K. Bopp and Evans (1973) found areas of 20 per cent and temperatures of 2000 K for star spots also on YY Gem. If the photospheric temperature is really 2800 K, and 2700 K is the temperature needed to fit the fast electron theory (the "observed" temperature), then some ideas can be gotten as to the size of the spots if a temperature is assumed for the spot region. Several temperatures in the range 1600-2000 K were used for the temperature of the spot. At T = 1750 K and 2700 K for the temperatures of the spot and observed temperature respectively, $\psi_p/\psi_s = 115$ and $\psi_{ps}/\psi_s = 86$. Thus,

equation (6) becomes

$$115(1 - S) + S = 86,$$

so that $S = 0.25$.

This means that a spot at a temperature of 1750 K would reduce the observed temperature of the star from its true photospheric temperature of 2800 K to 2700 K if the spot covered 25 per cent of the visible disk. However, in this temperature region, the radiation of the spot at 6496Å is negligible when compared to that of the star. Thus, $S = 0.25$ is a lower limit in this temperature range. In other words, if the temperature of the spot is less than about 2000 K, the spot must cover at least 25 per cent of the visible stellar disk in order to decrease the observed temperature by 100 K. For a reduction to 2600 K (as for event 26FE4B), the size of the spot needed is 45 per cent of the visible disk. These sizes correspond to 12.5 and 22.5 per cent respectively of the total surface area. Larger spots would result in a greater reduction in the observed temperature. However, as mentioned above, a cooler spot would still need to cover 25 per cent of the disk since it is already essentially black when compared to the photosphere. However, it should be emphasized that the observing program was not conducted in such a way as to make these results definitive. They have been presented only as a possible explanation for the necessity of allowing the temperature of the star to vary in the tables. It should be noted that the temperature changes occur in Table 4 for the stronger events. This would be expected if flares are associated with the spot regions. The larger the spot region, the more

and stronger is the expected activity and the lower the observed temperature would be.

Conclusions

How well does the fast electron model for flare activity explain the observed events? As mentioned earlier in the chapter, the wavelength independence of τ_o and n is the most important thing to look for when attempting to fit the theory to the observations. However, as can be seen from Tables 3 and 4, the values of τ_o proved to be very dependent on wavelength. The value of τ_o for the blue band was typically 3 to 5 times that for the uv band. An even greater discrepancy is found when the values for the red band are compared to those for the uv. In this case the values are 15 to 40 times as great for the red band as they are in the uv. In all cases the value of τ_o increased toward longer wavelengths. This must be considered a serious objection to the theory. The values of n for most of the events were fairly consistent with the theory. It was found that the theoretical curve is not extremely sensitive to changes in n of 0.1. The fact that n was found to be essentially wavelength-independent means that the flare light was fairly constant in color. However, for a light curve in a single color, the value of n needed to fit the data was not time-independent.

Figures 17-24 are the observed light curves with a "best fit" theoretical curve drawn from the observed points. For events that were fitted with two different values of μ^2 and T, it was found that even though the values of n and τ_o differed

for the two fits, the theoretical curves were indistinguishable in appearance from one another. For example, Table 3 shows that 90C3D was fitted for $\mu^2 = 5$ and T = 2800 K. Table 4 shows that the same event was fitted using $\mu^2 = 10$ and T = 2700 K. However, the plots of the theoretical curves obtained from the two different fits were essentially identical. Thus, from the fit of the curves to the observed data, a choice between the two sets of values for μ^2 and T was impossible. For event 90C3D, the value of n used in obtaining the curve fits the observations well throughout the curve. However, for other events (e.g. 21SE4) the value of n needed to describe the shape of the curve immediately following maximum is significantly larger than that needed for the later portions of the curve. This is exemplified by the observed curve dropping below the theoretical curve. This is not as serious an objection as that for the τ_o values or if the values of n in the 3 colors were very different. The value of n being a function of time means that the cloud does not expand in the same way during the later stages of the flare as it did immediately following maximum. Values of n immediately after maximum sometimes reached 3 or 4 for short portions of the curve and decreased as time went on. There were no cases where n became larger for the later parts of the curve. A few flares (e.g. 21FE4 and 90C3C) had values of n that showed significant differences for the different colors. This effect is not readily explained in the context of the theory. The event 21FE4 might possibly be explained as a long-lived

enhancement of Hα causing the red curve to decrease at a slower rate than uv or blue. However, 90C3C shows the red band decreasing faster. Though the theory was not applied to event 90C3A, as can be seen from Figure 25, the color of the flare light changed drastically during the event. This type of activity is totally unexpected in the context of the theory.

Thus it seems as if the fast electron theory falls short in its attempt to explain the phenomenon of stellar flares. The question of the different values of τ_o for the various bandpasses needs to be answered. Also, treatment of the emission lines and how they are affected during a flare should be considered. Last but not least, where does the cloud of suprathermal electrons come from?

Figure 17 - A fast electron model "best fit" for event 7003.

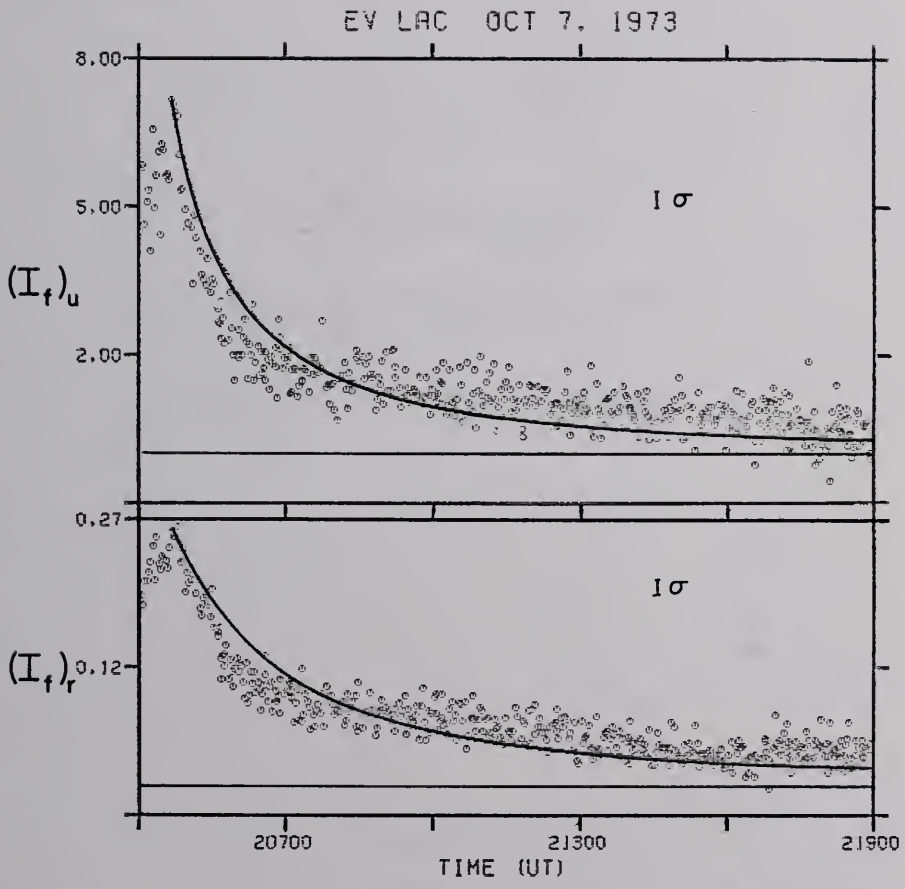

EV LAC OCT 7, 1973
8.00
5.00
2.00
$(I_f)_u$
1σ
0.27
0.12
$(I_f)_r$
1σ
20700
21300
21900
TIME (UT)

Figure 18 - A fast electron model "best fit" for event 90C3C.

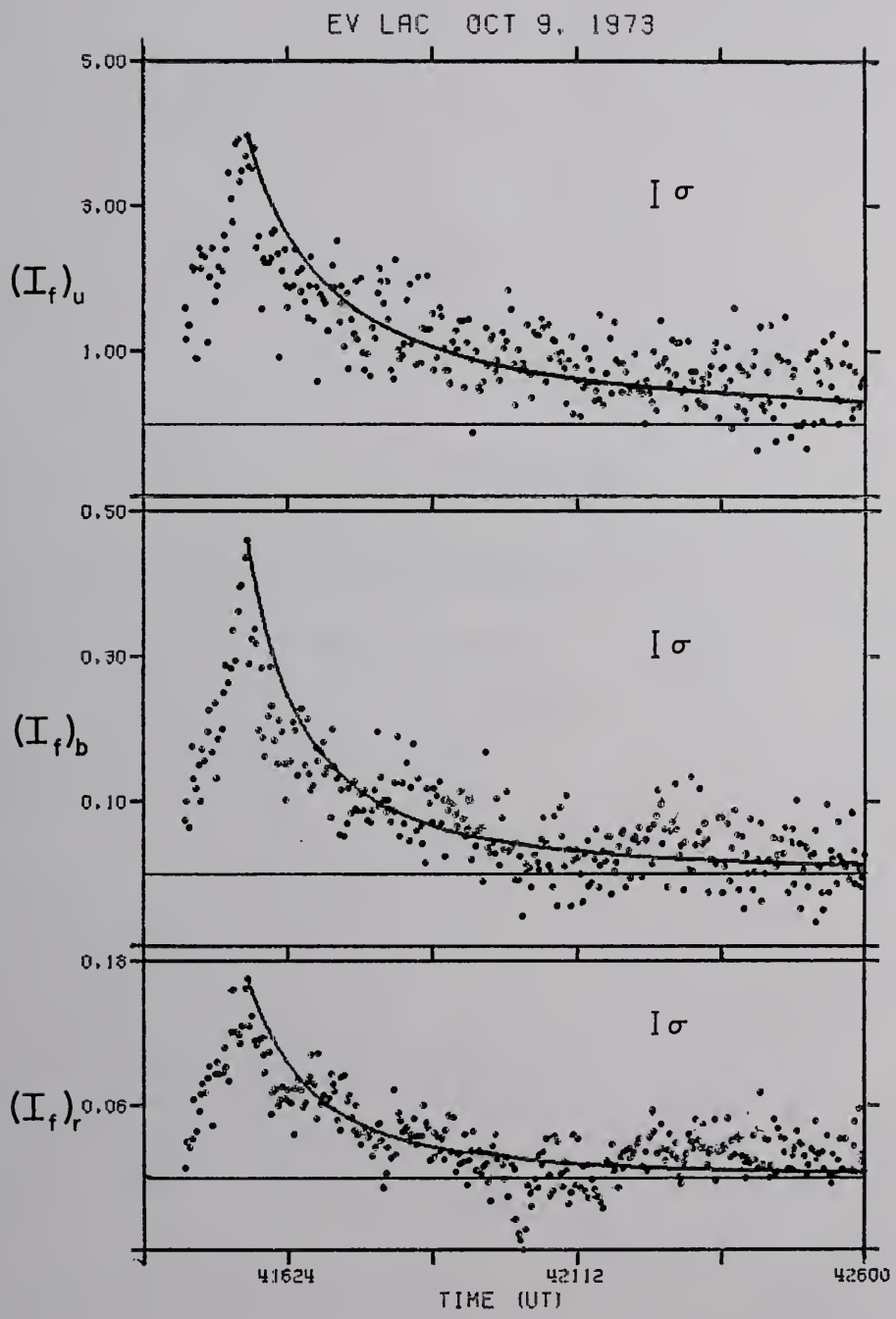

EV LAC OCT 9, 1973
5.00
3.00
1.00
$(I_f)_u$
1σ
0.50
0.30
0.10
$(I_f)_b$
1σ
0.18
0.06
$(I_f)_r$
1σ
41624
42112
42600
TIME (UT)

Figure 19 - A fast electron model "best fit" for event 90C3D.

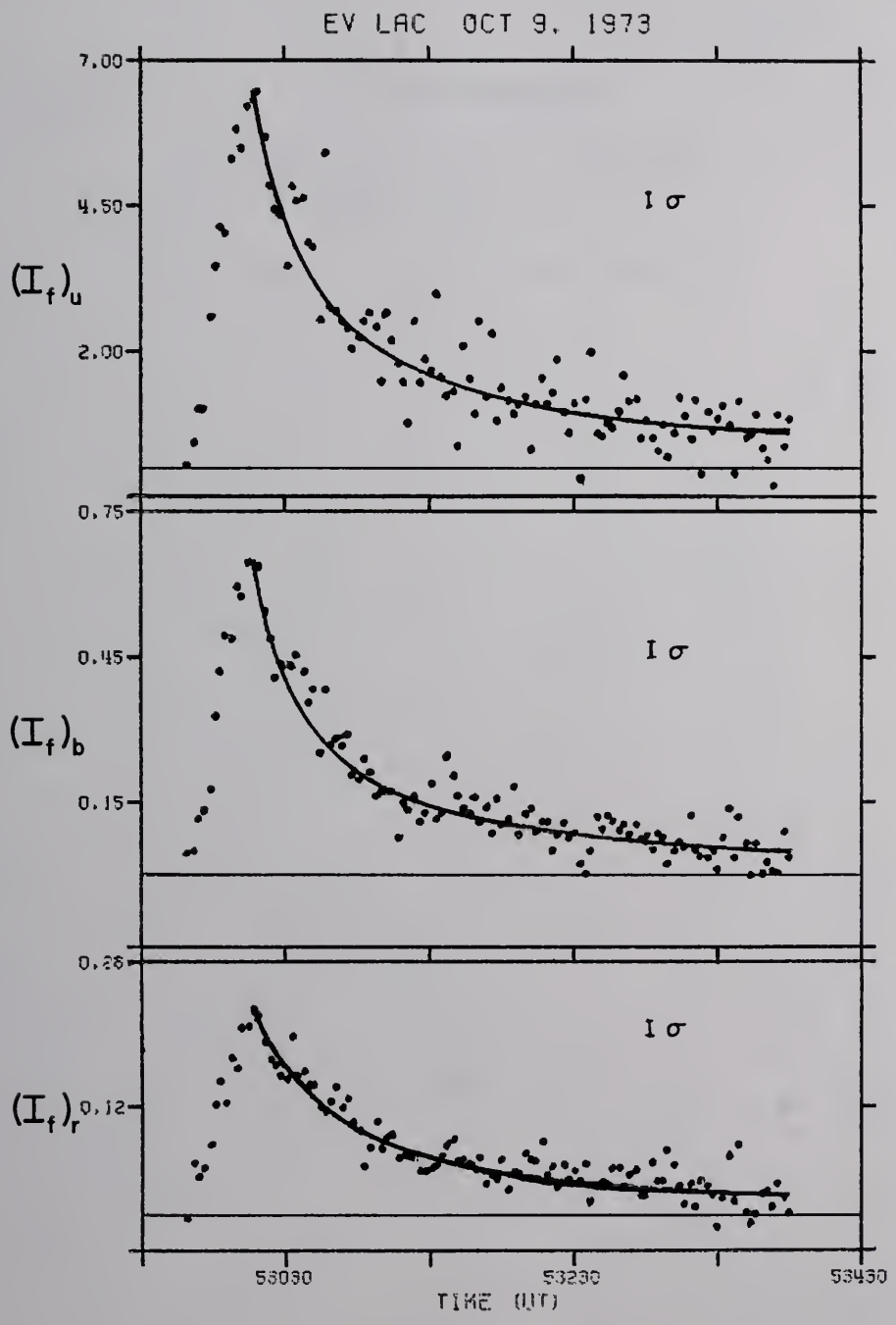

EV LAC OCT 9, 1973
7.00
4.50
2.00
$(I_f)_u$
I σ
0.75
0.45
0.15
$(I_f)_b$
I σ
0.28
0.12
$(I_f)_r$
I σ
53000
53230
53450
TIME (UT)

Figure 20 - A fast electron model "best fit" for event 21FE4.

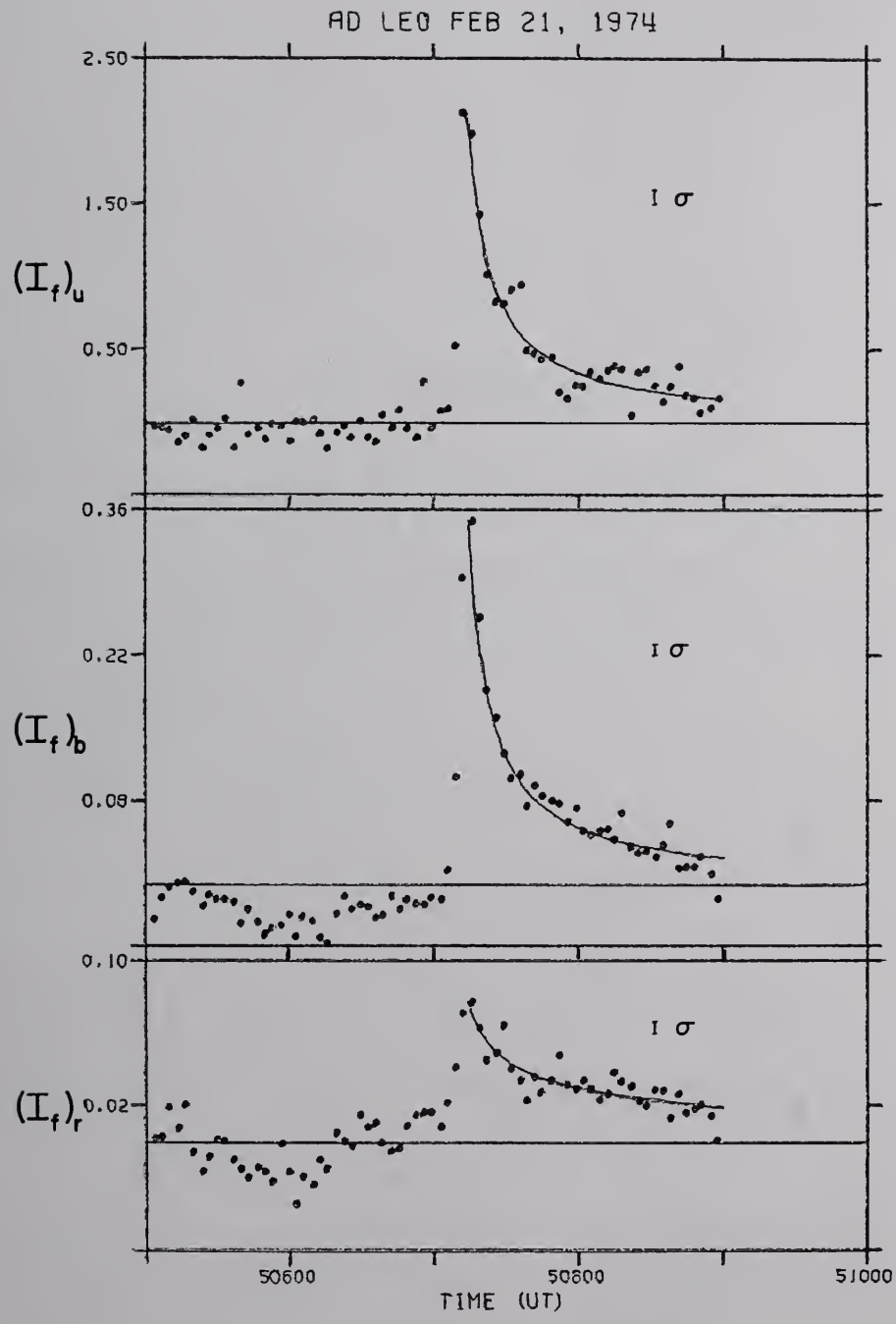

AD LEO FEB 21, 1974
2.50
1.50
0.50
$(I_f)_u$
1 σ
0.36
0.22
0.08
$(I_f)_b$
1 σ
0.10
0.02
$(I_f)_r$
1 σ
50600
50800
51000
TIME (UT)

Figure 21 - A fast electron model "best fit" for event 26FE4A. The maximum value of I_f in the blue bandpass was not observed due to amplifier saturation. A value of 1.50 was assumed.

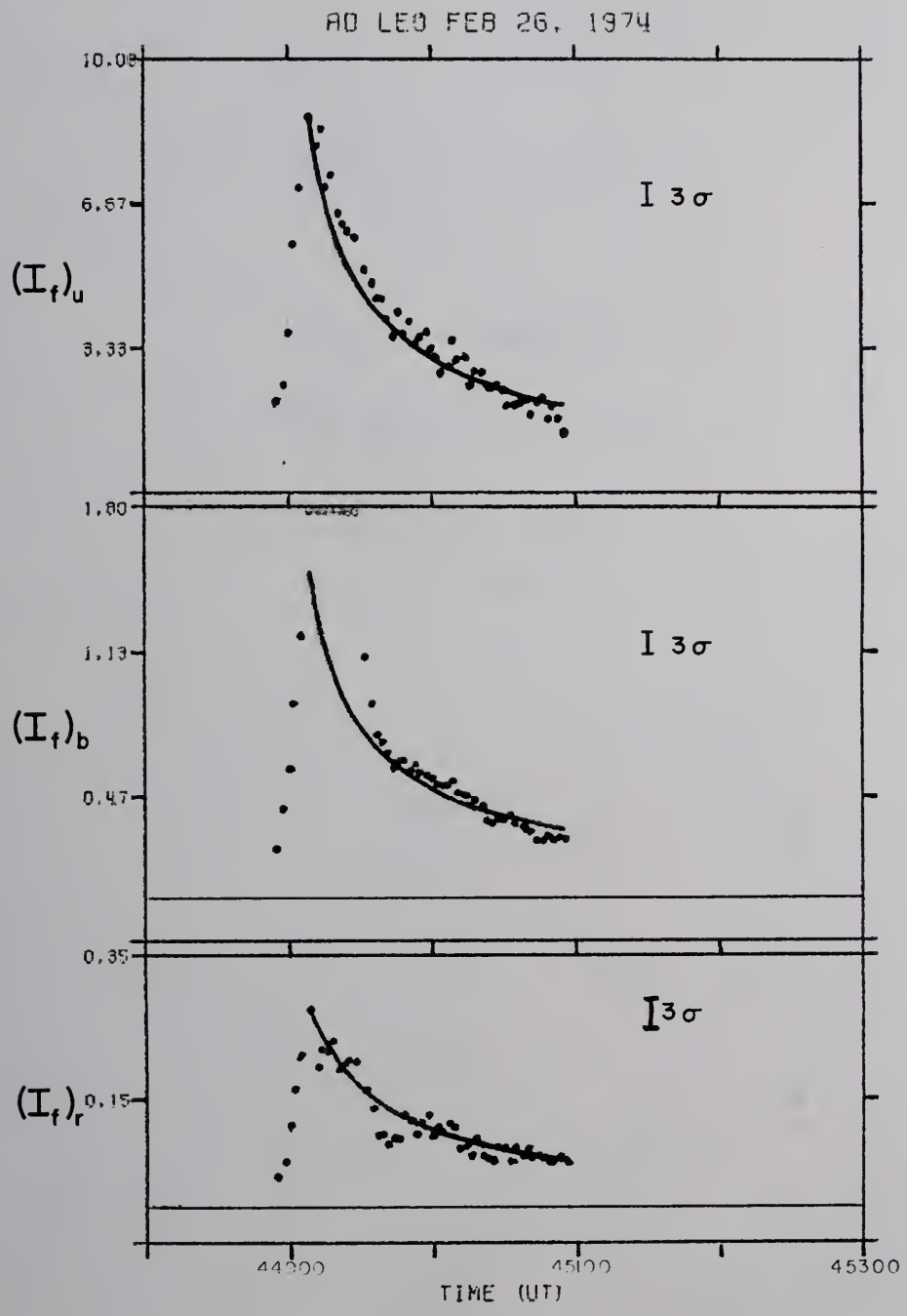

AD LEO FEB 26, 1974
10.00
6.67
3.33
1.80
1.13
0.47
0.35
0.15
$(I_f)_u$
$(I_f)_b$
$(I_f)_r$
I 3σ
I 3σ
I 3σ
44300
45100
45300
TIME (UT)

Figure 22 - A fast electron model "best fit" for event 26FE4B.

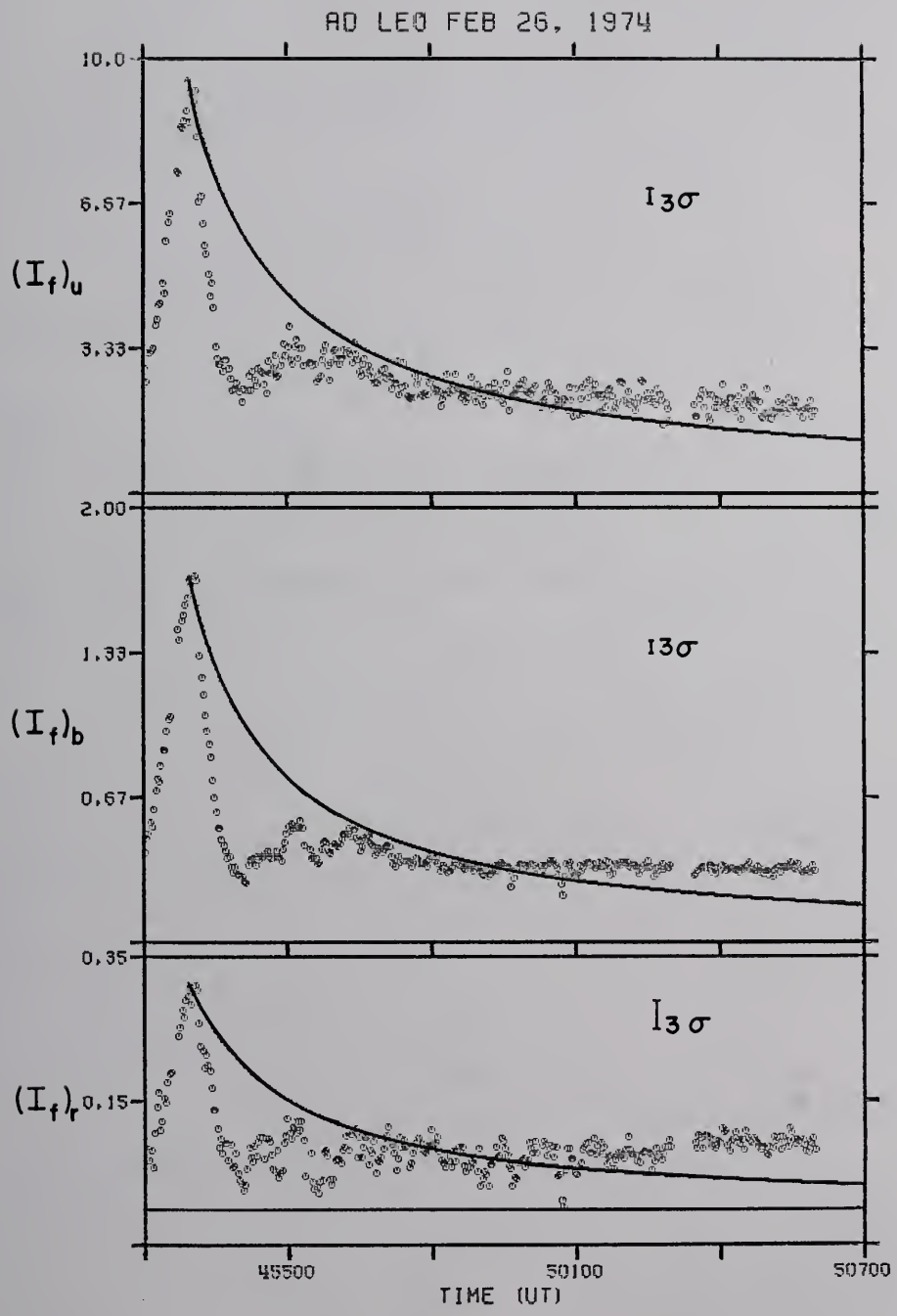

AD LEO FEB 26, 1974
10.0
6.67
3.33
2.00
1.33
0.67
0.35
0.15
$(I_f)_u$
$(I_f)_b$
$(I_f)_r$
$I_{3\sigma}$
$I_{3\sigma}$
$I_{3\sigma}$
45500
50100
50700
TIME (UT)

Figure 23 - A fast electron model "best fit" for event 25AP4.

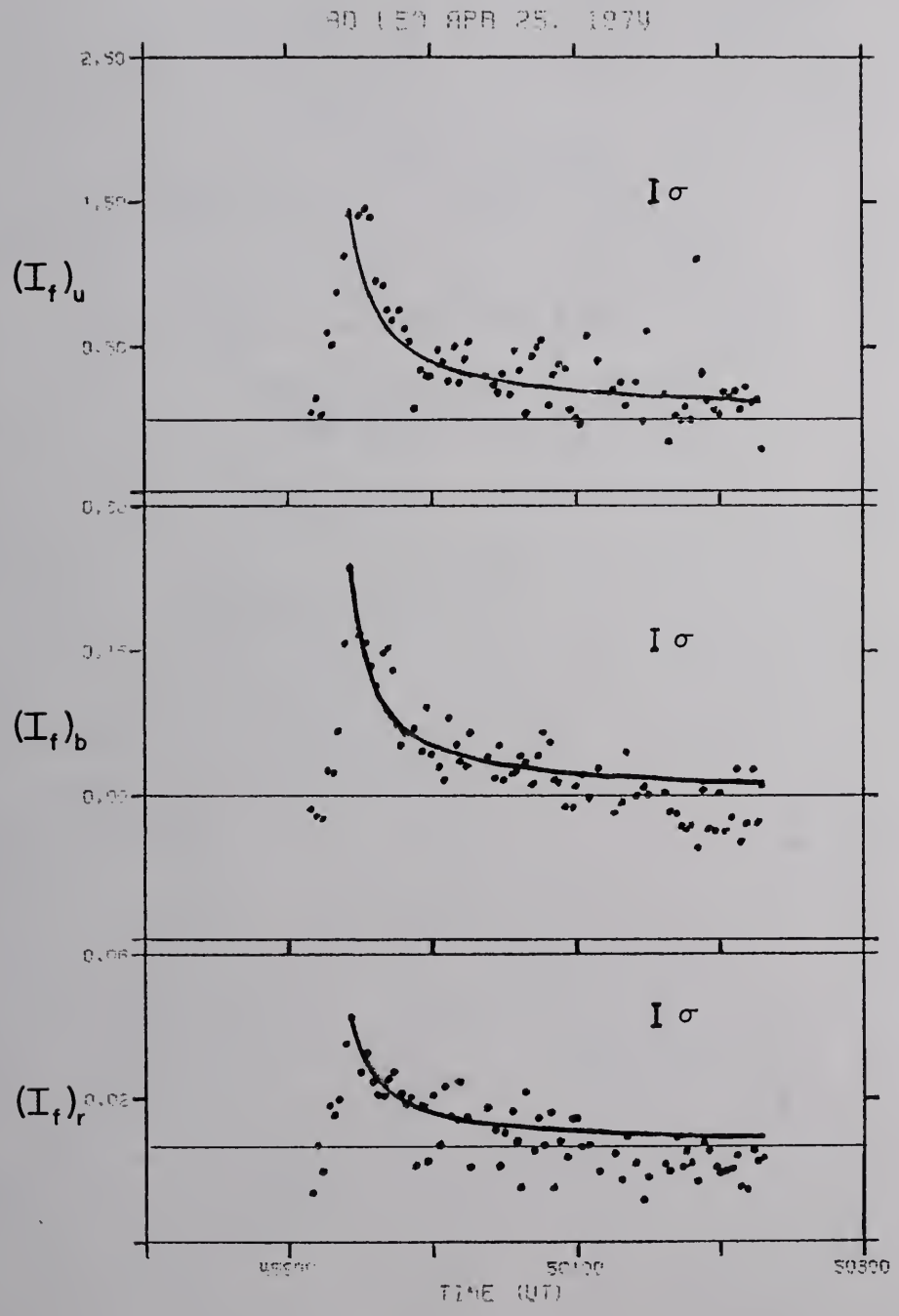

AO (59 APR 25, 1974
2.50
1.50
0.50
$(I_f)_u$
I σ
0.15
$(I_f)_b$
I σ
0.06
0.02
$(I_f)_r$
I σ
50300
TIME (UT)

Figure 24 - A fast electron model "best fit" for event 21SE4.

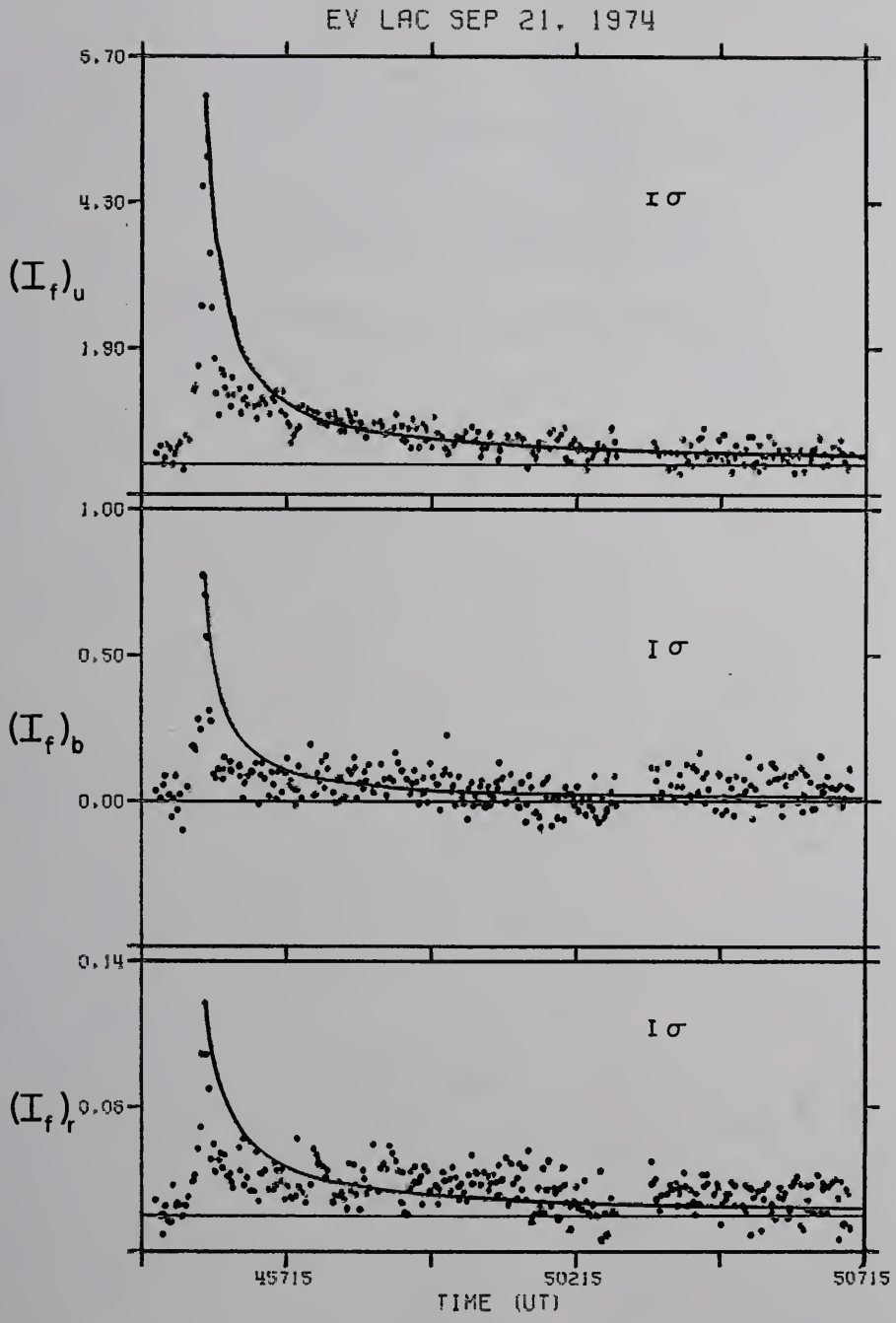

EV LAC SEP 21, 1974
5.70
4.30
1.90
1.00
0.50
0.00
0.14
0.06
$(I_f)_u$
$(I_f)_b$
$(I_f)_r$
1σ
1σ
1σ
45715
50215
50715
TIME (UT)

Figure 25 - Instrumental color indices of flare light for event 9003A.

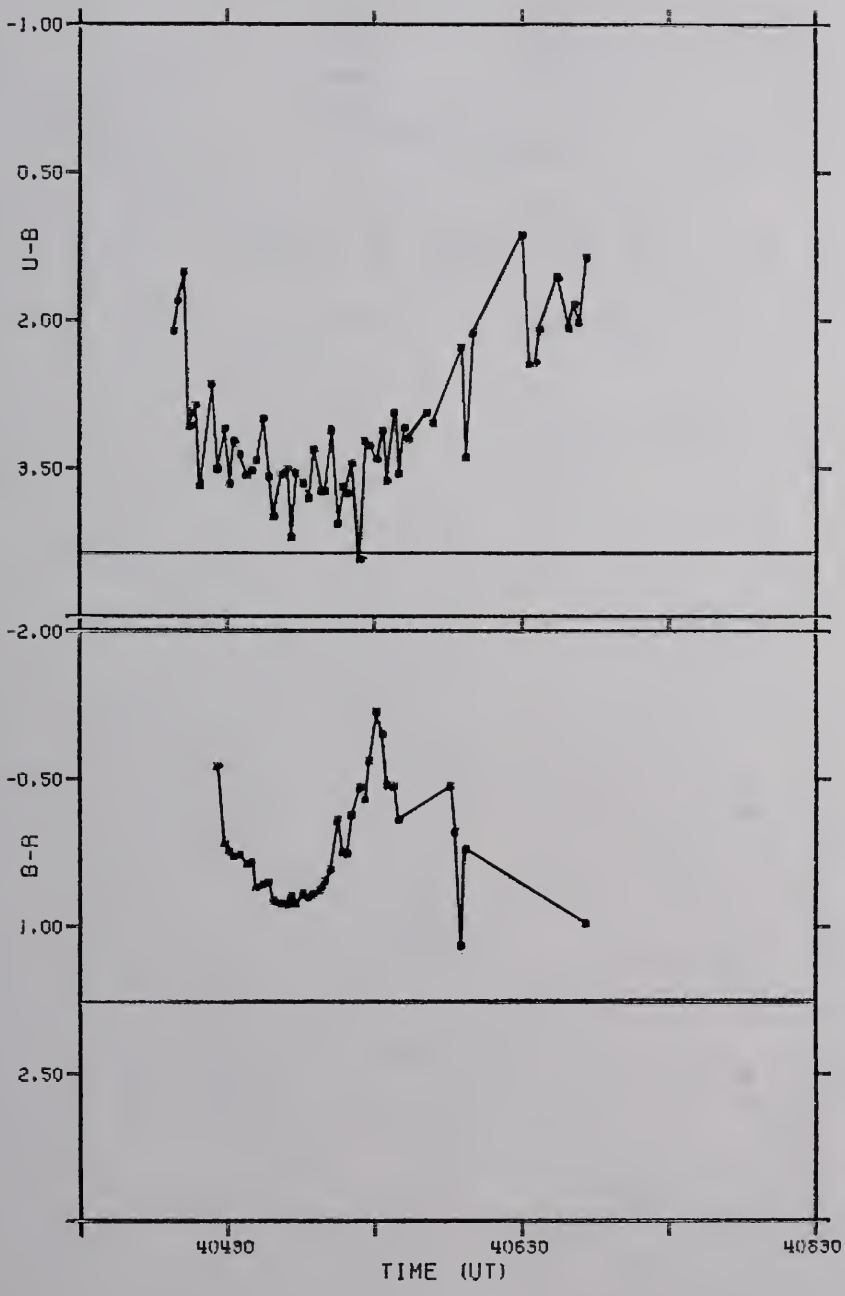

-1.00
0.50
2.00
3.50
U-B
-2.00
-0.50
1.00
2.50
B-R
40430
40630
40830
TIME (UT)

Figure 26 - Instrumental color indices of flare light
for events 90C3B,C.

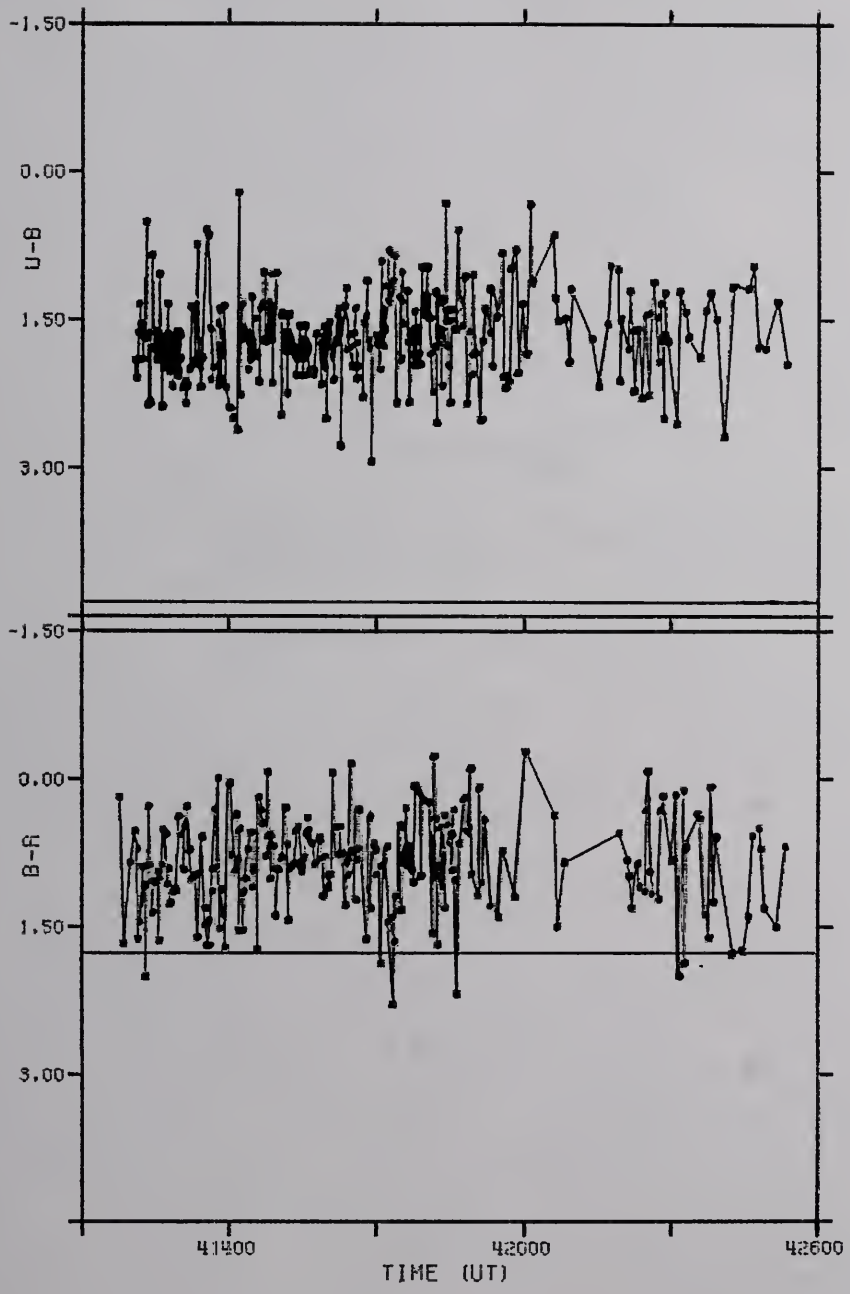

-1.50
0.00
1.50
3.00
U-B
-1.50
0.00
1.50
3.00
B-A
41400
42000
42600
TIME (UT)

Figure 27 - Instrumental color indices of flare light for event 90C3D.

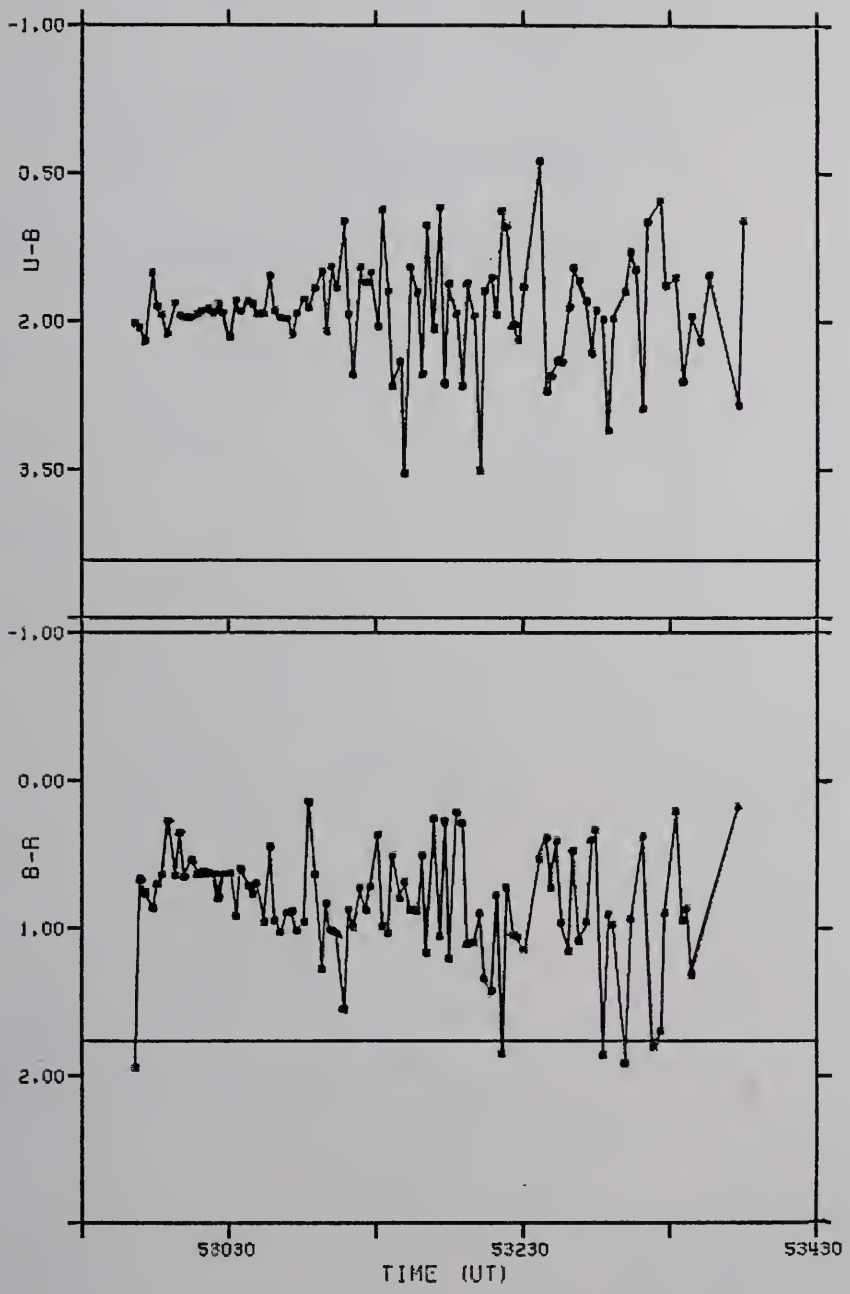

-1.00
0.50
2.00
3.50
U-B
-1.00
0.00
1.00
2.00
B-R
53030
53230
53430
TIME (UT)

Figure 28 - Instrumental color indices of flare light for event 26FE4B.

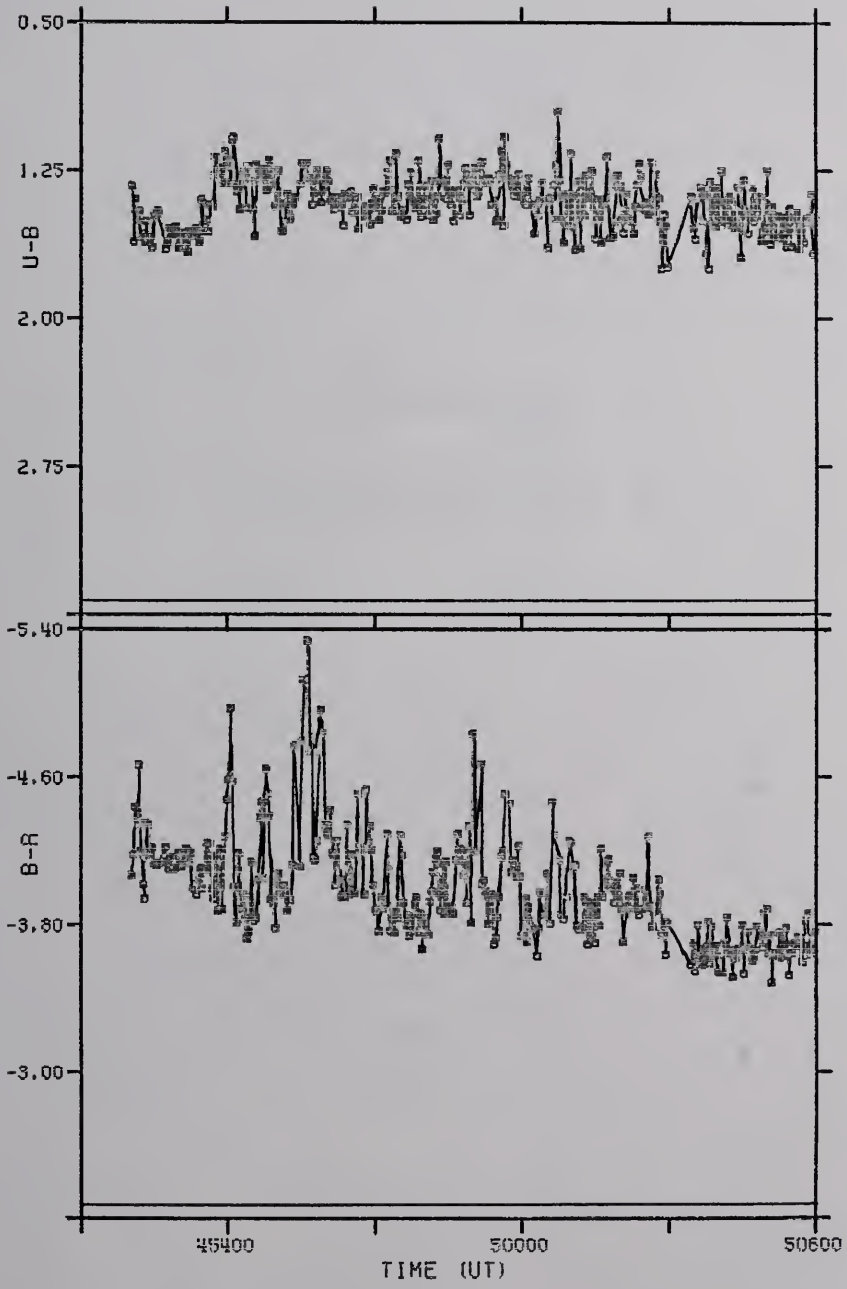
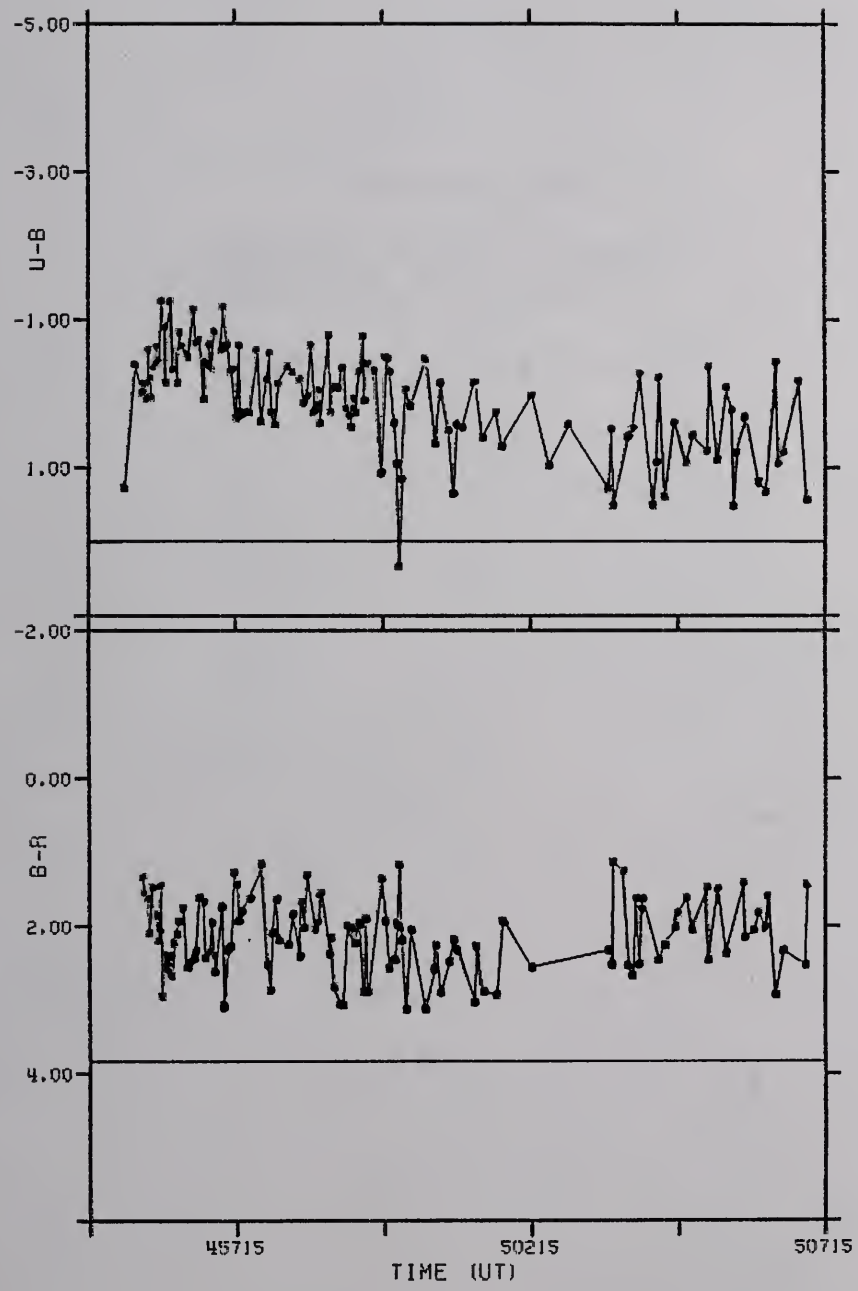

0.50
1.25
U-B
2.00
2.75
-5.40
-4.60
B-R
-3.80
-3.00
45400
50000
50600
TIME (UT)

Figure 29 - Instrumental color indices of flare light for event 21SE4.


-5.00
-3.00
U-B
-1.00
1.00
-2.00
0.00
B-A
2.00
4.00
45715
50215
50715
TIME (UT)

CHAPTER V

FLARE COLORS

The most immediate applications of multicolor simultaneous photometry are twofold. The shapes of the light curves in the various bandpasses can be obtained without the need for interpolations and extrapolations, thereby making more complex features in the light curves easier to study (Moffett 1972). In addition, the colors of the flare light itself can be obtained with far greater accuracy than is possible with filter-changing systems.

The observing program for this study provided the ability to directly measure the color indices, u-b and b-r, of the flare light with a typical time resolution of 2 seconds.

As discussed in Chapter IV, the flare light was essentially constant in color in most cases. Of the strongest events, from which good color data could be obtained, only event 90C3A showed anomalous behavior (Figure 25). Figures 26-29 show the observed instrumental color indices of the flare light as a function of time for the strongest events. The quiet color of the star is represented on the plots by a horizontal line. Plotted were only those points for which the observed intensities in both of the bands used to obtain the color index were at least 1 standard deviation above the quiet levels of the star.

Rather than the instrumental color indices, which are subject to night-to-night variations in amplifier response, arbitrary zero points for the magnitude scales, etc., a more meaningful parameter is the differential color index between the flare light and the quiet star. Table 5 lists the differential color indices (flare light - quiet star) for all of the observed flares. The indices were calculated using the values of I_f at maximum light. It should be noted that the b-r index for event 18AP5 is very uncertain due to the erratic shape of the red light curve (see Figure 16). Also, the indices for event 26FE4A were obtained using the assumed value of 1.50 for I_f in the blue bandpass, as noted in Chapter IV. The index quoted for event 70C3 is u-r, since it was only observed in those two bands. Table 6 lists the average values for the differential color indices. The uncertainties quoted are standard deviations. The table seems to indicate that there is less variation in the color indices of the flare light for AD Leo than for EV Lac. A possible explanation is that the contribution of the emission-line radiation in the events observed was more variable in the case of EV Lac than for AD Leo. That is, for the flares observed, the emission-line radiation may have contributed more to the flare light for some flares on EV Lac than others, but was relatively consistent in its contribution to the flare light on AD Leo. This explanation would agree with the findings in Chapter IV that in most cases where the red light curves could not be fitted using the initially assumed parameters for

Table 5

DIFFERENTIAL COLOR INDICES (FLARE LIGHT - QUIET STAR) AT TIME OF MAXIMUM LIGHT FOR OBSERVED EVENTS ON EV LAC AND AD LEO

Star	Event	u-b	b-r
EV Lac	26AU3	-2.74	-0.59
	3SE3	-2.55[a]	-0.96
	70C3	-3.60[a]	
	90C3A	-1.12	-1.02
	B	-2.66	-0.75
	C	-2.37	-1.12
	D	-2.50	-1.13
	19AU4	-2.12	-1.39
	21SE4	-2.23	-2.06
AD Leo	21FE4	-1.96	-1.60[b]
	26FE4A	-1.90	-1.86[b]
	B	-1.88	-1.84
	27FE4	-2.13	-1.67
	25AP4	-1.95	-1.95
	18AP5	-1.96	-1.12

[a] This color index is u-r, since the event was only observed in 2 colors.

[b] Both indices based on assumed value of maximum value of 1.50 for I_f in the blue bandpass.

the fast electron theory, the flares were of EV Lac.

Table 6

AVERAGED DIFFERENTIAL COLOR INDICES (FLARE LIGHT - QUIET STAR) FOR OBSERVED EVENTS ON EV LAC AND AD LEO

Star	u-b	b-r	Comments
EV Lac	-2.45 ± 0.09	-1.14 ± 0.18	90C3A excluded
	-2.29 ∓ 0.19	-1.13 ∓ 0.16	all events
AD Leo	-1.96 ± 0.04	-1.67 ± 0.12	all events
	-1.96 ∓ 0.04	-1.78 ∓ 0.06	18AP5 excluded

Eggen's (1968) values for the color indices of AD Leo and EV Lac indicate that the energy distributions for the two stars are, to a first approximation, the same. Thus, the color indices of AD Leo and EV Lac can be treated as respectively equal. Therefore, the observed differential color indices for the flare light can be directly compared for flares on both stars. Figure 30 is a color-color plot of the differential color indices for the observed flares. An interesting relation seems to exist, for 11 of the 14 flares which were observed in 3 colors fall very close to a straight line. The interesting thing is that the smaller the u-b color index for the flare light, the larger is the b-r index. Of the three-color events which deviate the most from the relation, 2 show anomalous behavior in the red bandpass. Event 90C3A has already been mentioned. The amplitude in r was unusually large and the curve shows dips below the quiet

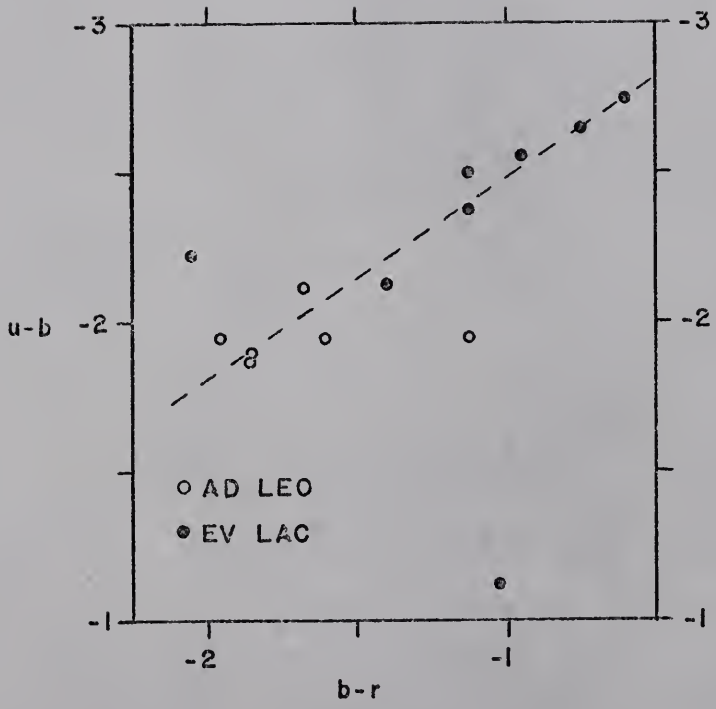


Figure 30 - Plot of observed differential color indices of flare light for flares of AD Leo and EV Lac.

level of the star. The flare also showed an ultraviolet deficiency when compared with the amplitude of the light curve in the blue bandpass (see Figure 7). The other anomalous event was 18AP5. For this event, the r light curve showed no clearly defined maximum, but exhibits a quasi-sinusoidal shape (Figure 16). The dashed line on the plot represents a linear least squares fit to the 11 flares which define the straight line. The relation, $u-b = -3.15 - 0.66(b-r)$, can be explained as being due to a greater enhancement of the Balmer lines during flares whose continuum radiation shows the smaller values of u-b. As mentioned previously, flare light shows a continuum energy distribution for which color temperatures are in excess of 10,000 K. When light with this distribution is superimposed on that of a dM object, the ultraviolet region of the spectrum will show the greatest relative change. It is well known that the Balmer lines are greatly enhanced during flare activity (see Joy 1960; Kunkel 1967; Joy and Humason 1949). The change in intensity of the $H\alpha$ and $H\beta$ lines has a significant affect in the overall response of the three-channel system in the red bandpass (see Figure 1 and the discussion in Chapter IV). Thus, the red bandpass will show the greatest sensitivity to the enhancement in the Balmer lines. This means that for events which show strong emission-line enhancement, the b-r index will be redder than if the radiation were simply continuum. However, it remains to be explained why flare light which shows the greatest enhancement in the emission lines should

also have the smallest u-b color index.

The anomalous colors for event 90C3A can be explained if the H_γ and $H\delta$ lines were enhanced more than usual, thereby causing the amplitude in b relative to that in u to be greater than normal.

Other published observations of flare events in three colors have been relatively rare (e.g. Moffett 1974; Abell 1959). A color-color plot was made for all of the events observed by Moffett and the one such event observed by Abell, but no relation such as that seen in Figure 30 was found. This is not surprising since all of the observations by Moffett and Abell were carried out in the UBV bandpasses. If, indeed, the Balmer line-emission is the cause of the behavior of the b-r color index, the Johnson V would not show it, since the V band is not sensitive to the $H\alpha$ line. However, broadband photometry can obviously not answer the question definitively.

CHAPTER VI

CONCLUSIONS AND FUTURE RESEARCH

Conclusions

This investigation into the phenomenon of stellar flares has involved several aspects about which meaningful conclusions can be drawn.

The entire program would have been impossible if the three-channel photometer system had proved unfeasible. All other types of multicolor systems sacrifice either flux, time resolution, or both. These are serious drawbacks, especially when involved in a program concerned with the phenomenon of stellar flares. By using dichroic mirrors and reflection filters, very high efficiency was obtained in the definition of the various bandpasses, thereby allowing the high time resolution to be obtained. The system is currently being used in connection with two other programs and continues to provide reliable, high quality data.

As a result of the practicality of the three-channel system, the first truly simultaneous three-color light curves of flare events were obtained. The majority of the events produced curves that would have been expected. The rapid rise and slower decay characteristic of stellar flares

were seen in all events. However, the curves for some events showed unexpected characteristics. Event 90C3A has been discussed at length. The event 18AP5 exhibited strange behavior in the red bandpass. These events would not have revealed this strange behavior if the monitoring had been carried out in the traditional Johnson U or B bands.

The application of theory to the observed data allowed conclusions to be drawn that would have been impossible had it not been for the multicolor nature of the observations. It was found that the fast electron model proposed by Gurzadyan does not adequately fit the observed data. The major difficulties lie in the observed wavelength dependence of the maximum value of the optical depth of the proposed electron cloud and the lack of treatment of line emission behavior during flare activity. In all observed events, the optical depth decreased for shorter wavelengths. This difference ranged from a factor of 15 to 40 when the optical depths found from the r observations were compared with those in the u.

Evidence of an unexpected relationship between the u-b color index and the b-r index of flare light at maximum was found. The relationship is of the form $u-b = -3.15 - 0.66(b-r)$, and is most pronounced for flares of EV Lac. The relationship, if real, probably is involved with the relative importance of emission-line radiation to the continuum radiation.

Agreement with the theory was found in the fact that the colors of the flare light were essentially constant

throughout the duration of the stronger flares. This was true for the ascending portion of the curve as well as for after maximum. However, 90C3A was again found to be anomalous, as the colors continually changed throughout the event.

Future Research

The time has come in the area of flare star research for observing programs to become more carefully chosen as to the equipment employed. Single-channel broad band photometry will add little to our understanding of the physical processes involved in stellar flares. Programs in photoelectric photometry need to emphasize multicolor simultaneous monitoring, preferably in at least three colors. Also, narrow band photometry (e.g. Hα) would be very useful, especially if done in conjunction with the multicolor photometry. This type of monitoring would give clues as to the frequency of the anomalous type of events such as 90C3A observed during the present program. It would also provide a much better feeling for the amount of the contribution of line emission to flare light and the degree to which this contribution is variable. This would help explain the relation that seems to exist in the color-color plot for the flares observed in this study. The multicolor bandpasses should be chosen to include the Hα line. This would rule out the Johnson V.

The importance of high time resolution has already been pointed out and should be of prime concern in all types of

observation. Moffett (1972) suggests at least 1 second time resolution for photoelectric observation. Most of the work done in the present study has a time resolution of 2 seconds, and it is my feeling that at least this resolution is needed in each color of multicolor observations.

Polarimetry measurements of flare light have been more scarce than three-color photometry (see Grigoryan and Eritsyan 1971; Grinin and Domke 1971). Measures of the degree of polarization and polarization angle of flare light would prove useful. Of special interest would be measures made in narrow band regions of the spectrum around emission lines.

Radio observations of flares have been comparatively few until recently (see Lovell, Whipple, and Solomon 1963; 1964; Lovell and Chugainov 1964; Weber, Yoss, Deming, Yang, and Green 1973). Spangler et al. (1974a; b) have observed radio flares and have measured the polarization of the flare flux using instrumentation at the Arecibo observatory. Observations such as these, especially if done in conjunction with photoelectric observations and optical polarimetry, would prove very useful in the formulation and testing of theory.

Finally, and perhaps most important, high time-resolution spectra of flare stars during flare events are needed. This type of observation would provide the most useful information as to the behavior of emission and absorption features as well as the continuum radiation during flares. I believe

that it is through the high time-resolution spectra that the next major step in the understanding of stellar flares, and through them, solar flares, will be made.

APPENDIX 1

TIMES OF COVERAGE OF PROGRAM STARS

This appendix lists the dates and times of coverage of the four program stars. Times are given in Universal Time, with breaks in the coverage of approximately 1 minute or more being noted.

YZ CANIS MINORIS

DATE	COVERAGE (UT)	TOTAL
28 JUN 73	0619-0621 0623-0633 0637-0653 0656-0711 0714-0736 0740-0748 0752-0754	1 h 22 m
1 JUL 73	0352-0411 0413-0425 0449-0507 0529-0548 0554-0603 0607-0619 0628-0641 0646-0704 0708-0718 0728-0732 0739-0747	2 33
2 JUL 73	0338-0403 0408-0423 0426-0456 0508-0515 0519-0530 0543-0557 0601-0618 0622-0623 0628-0641	2 22
4 JUL 73	0506-0520 0522-0533 0536-0552 0556-0616 0622-0635 0639-0650 0654-0709 0712-0722	1 58
	TOTAL COVERAGE	8 h 15 m

BD+16 2708

DATE	COVERAGE (UT)	TOTAL
29 APR 74	0431-0500 0502-0542	1 h 09 m
20 MAY 74	0428-0503 0505-0539 0540-0617 0619-0652 0655-0708	2 32
29 MAY 74	0148-0156 0446-0503 0507-0533 0535-0551 0554-0556	1 09
23 JUN 74	0248-0316 0318-0348 0350-0413 0415-0430	1 36
20 JUL 74	0311-0340 0344-0413 0416-0428	1 10
	TOTAL COVERAGE	7 h 36 m

EV LACERTAE

DATE	COVERAGE (UT)	TOTAL
4 JUL 73	0808-0812 0815-0826 0828-0844 0846-0902 0911-0923	$1^h 04^m$
5 AUG 73	0543-0551 0552-0603 0606-0633 0635-0705 0707-0726 0745-0809 0813-0828 0831-0836 0839-0905 0915-0921	2 58
7 AUG 73	0437-0447 0525-0551 0555-0622 0625-0651 0807-0828 0831-0858 0901-0915	2 37
26 AUG 73	0553-0608 0611-0632 0635-0657 0700-0717	1 19
30 AUG 73	0326-0331 0332-0342 0343-0355 0358-0428 0430-0459 0502-0526 0530-0550 0601-0607	2 14
3 SEP 73	0518-0545 0548-0620 0622-0649 0651-0735 0741-0750 0753-0809 0810-0831	3 03
7 OCT 73	0126-0152 0154-0222 0225-0256 0258-0317 0322-0330 0347-0416 0420-0448 0451-0510	3 08
9 OCT 73	0328-0426 0430-0501 0503-0539 0541-0608 0610-0637 0639-0708 0710-0721	3 46
3 DEC 73	0212-0219 0223-0253 0257-0323 0327-0330 0332-0352	1 26
15 AUG 74	0353-0428 0430-0436 0437-0500 0503-0535 0537-0612 0614-0643 0701-0734 0737-0810 0812-0843 0845-0908 0910-0931	5 01
19 AUG 74	0158-0201 0342-0411 0414-0454 0455-0540 0542-0630 0646-0724	3 23
13 SEP 74	0146-0218 0220-0240 0346-0423 0521-0545 0551-0602	2 04
17 SEP 74	0142-0214 0216-0247 0249-0308 0314-0323	1 31
18 SEP 74	0335-0350 0430-0507 0508-0529 0546-0552	1 19
21 SEP 74	0154-0221 0223-0235 0236-0309 0311-0347 0349-0407 0411-0421 0423-0437 0448-0517 0519-0549 0552-0619 0620-0625 0628-0702 0704-0737 0739-0800	5 29
11 OCT 74	0540-0612 0615-0645 0647-0711 0714-0735	1 47
12 OCT 74	0020-0050 0052-0123 0124-0202 0204-0233 0249-0323 0326-0410	3 26
15 OCT 74	0058-0137 0145-0147 0149-0215 0217-0229 0231-0235 0316-0336 0338-0420 0422-0435 0438-0454 0456-0533 0535-0544 0547-0607 0609-0641 0643-0650	4 39
	TOTAL COVERAGE	$50^h 14^m$

AD LEONIS

DATE	COVERAGE (UT)	TOTAL
22 JAN 74	0304-0334 0338-0355 0356-0412 0415-0436 0438-0448 0455-0521 0529-0542 0543-0600 0609-0618 0758-0800 0805-0817	2h 53m
23 JAN 74	0256-0259 0310-0329 0331-0332 0339-0340 0342-0358 0401-0440 0443-0519 0522-0537 0649-0659 0701-0703 0707-0719 0735-0813 0815-0849 0851-0859 0901-0909 0911-0918	4 09
18 FEB 74	0136-0200 0203-0236 0239-0308 0310-0339 0341-0409 0411-0427	2 39
21 FEB 74	0254-0303 0313-0334 0337-0409 0411-0439 0442-0511 0514-0532 0615-0641 0644-0714 0716-0744 0746-0814 0817-0833 0838-0848 0850-0905	4 50
26 FEB 74	0243-0313 0315-0345 0347-0416 0418-0446 0506-0519 0522-0547 0611-0648 0651-0723 0732-0758 0801-0824	4 33
27 FEB 74	0110-0139 0142-0210 0213-0244 0247-0250 0252-0326 0328-0400 0403-0406 0410-0436 0438-0507 0509-0543 0602-0632 0634-0704 0707-0716 0721-0733 0736-0805 0808-0816 0818-0833	6 22
4 MAR 74	0458-0531 0533-0610 0613-0646 0648-0722 0724-0743 0748-0802 0804-0823 0825-0835 0837-0847 0850-0920	3 59
20 MAR 74	0229-0308 0309-0340 0342-0413 0430-0506 0509-0541 0543-0619 0621-0641	3 45
10 APR 74	0109-0136 0138-0206 0208-0238 0240-0302 0311-0324 0327-0349 0351-0417 0420-0437 0440-0444 0446-0515 0517-0539 0545-0556	4 11
22 APR 74	0125-0129 0132-0203 0205-0243 0245-0316 0317-0339 0341-0350 0359-0416	2 32
25 APR 74	0118-0150 0152-0232 0237-0307 0310-0342 0344-0419 0421-0453 0455-0533	3 59
28 APR 74	0112-0143 0145-0218 0220-0250 0251-0321 0323-0355 0357-0418	2 57
29 APR 74	0114-0145 0146-0221 0223-0253 0254-0327 0329-0346	2 26
20 MAY 74	0207-0212 0336-0352	21
15 FEB 75	0456-0529 0530-0605 0606-0635 0642-0712 0714-0747 0748-0818 0820-0855 0859-0910 0917-0927 0929-0940	4 17
15 MAR 75	0628-0704 0706-0729	59
18 APR 75	0138-0208 0210-0216 0218-0251 0253-0309 0311-0324 0325-0355 0357-0424	2 35
	TOTAL COVERAGE	57h 27m

APPENDIX 2

TABULATION OF OBSERVED CHANGES IN INTENSITY FOR FLARES OF EV LAC AND AD LEO

This appendix consists of the individual observations of all the major events observed. The changes in intensity listed for flares of EV Lac are relative to the total light of the system. The notation used is as follows:

TIME : is the Universal Time of the observation in hours, minutes, and seconds,

U : the observed I_f in the uv bandpass,

B : the observed I_f in the b bandpass, and

R : the observed I_f in the r bandpass.

I_f is the change in intensity relative to the quiet level of the star, as defined in Chapter III.

EV LAC AUG 26, 1973

TIME	U	B	R	TIME	U	B	R
055801	0.004	0.005	0.000	060019	0.529	0.040	0.019
055803	-0.168	0.015	0.009	060021	0.229	0.074	0.034
055806	-0.029	0.032	0.004	060024	0.531	0.062	0.031
055808	-0.007	0.057	0.013	060026	0.354	0.094	0.018
055810	0.164	0.007	0.022	060028	0.408	0.071	0.028
055812	0.271	0.005	0.005	060030	0.480	0.045	0.010
055815	-0.108	0.035	0.030	060033	0.246	0.084	0.030
055817	0.043	0.029	0.035	060035	0.547	0.072	0.053
055819	-0.005	0.036	-0.000	060037	0.448	0.085	0.050
055822	-0.245	0.011	0.013	060040	0.124	0.042	0.041
055824	-0.082	0.034	-0.007	060042	0.300	0.028	0.028
055826	0.155	0.072	0.015	060044	0.124	0.051	0.048
055829	-0.112	0.024	0.026	060047	0.414	0.079	0.058
055831	-0.186	-0.003	0.023	060049	0.411	0.067	0.042
055833	0.157	0.048	0.014	060051	0.226	0.053	0.024
055835	0.689	0.082	0.016	060053	0.320	0.071	0.054
055838	0.362	0.025	0.020	060056	0.434	0.038	0.064
055840	0.211	0.012	0.023	060058	0.390	0.061	0.017
055842	0.454	0.027	0.041	060100	0.214	0.041	0.045
055845	0.464	0.063	0.034	060103	0.501	0.076	0.041
055847	0.247	0.071	0.036	060105	0.374	0.060	0.023
055849	0.593	0.093	0.041	060107	0.358	0.040	0.051
055852	0.320	0.096	0.042	060110	0.874	0.033	0.041
055854	0.474	0.069	0.033	060112	0.315	0.020	0.035
055856	0.651	0.071	0.026	060114	0.523	0.054	0.049
055858	0.526	0.032	0.032	060116	0.570	0.076	0.037
055901	0.440	0.055	0.016	060119	0.169	0.033	0.030
055903	0.650	0.073	0.046	060121	0.456	0.023	0.039
055905	0.738	0.098	0.042	060123	0.649	0.037	0.021
055908	0.281	0.120	0.036	060126	0.464	0.044	0.034
055910	0.220	0.073	0.012	060128	0.220	0.061	0.021
055912	0.376	0.069	0.029	060130	0.435	0.050	0.014
055915	0.222	0.064	0.028	060133	0.400	0.072	0.005
055917	0.084	0.076	0.008	060135	0.221	0.044	0.012
055919	0.335	0.063	0.020	060137	0.442	0.072	-0.001
055921	0.159	0.039	0.029	060139	0.266	0.058	0.007
055924	0.503	0.091	0.045	060142	0.452	0.077	0.036
055926	0.382	0.068	0.030	060144	0.459	0.050	0.039
055928	0.618	0.069	0.021	060146	0.590	0.064	0.013
055931	1.124	0.077	0.020	060149	0.092	0.063	0.016
055933	0.073	0.087	0.004	060151	0.323	0.053	0.051
055935	0.384	0.070	0.015	060153	0.629	0.068	0.039
055938	0.689	0.048	0.040	060156	0.461	0.063	0.049
055940	0.229	0.068	0.027	060158	0.430	0.082	0.104
055942	0.380	0.071	0.019	060200	0.562	0.109	0.119
055944	0.785	0.100	0.033	060202	0.119	0.105	0.058
055947	0.449	0.058	0.028	060205	0.137	0.103	0.050
055949	0.660	0.058	0.019	060207	0.405	0.076	0.040
055951	0.709	0.056	0.010	060209	-0.039	0.038	0.026
055954	0.400	0.025	0.034	060212	0.147	-0.007	0.008
055956	0.802	0.044	0.035	060214	0.297	0.031	0.031
055958	0.098	0.047	0.036	060216	0.269	0.033	0.021
060001	0.149	0.078	0.034	060219	0.343	0.009	0.030
060003	0.478	0.077	0.023	060221	-0.002	0.032	0.041
060005	0.415	0.103	0.036	060223	0.306	0.041	0.028
060007	0.338	0.082	0.027	060225	0.141	-0.003	0.025
060010	0.464	0.063	0.025	060228	0.431	0.011	-0.010
060012	0.212	0.075	0.039	060230	0.238	0.008	0.002
060014	0.388	0.052	0.013	060232	0.030	0.025	0.020
060017	0.428	0.082	0.035	060235	0.259	0.045	0.020

APPENDIX 2 - CONTINUED

EV LAC AUG 26, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
060237	0.393	0.033	0.024	060455	0.299	-0.017	0.019
060239	0.214	0.038	-0.004	060457	-0.016	0.004	0.002
060242	0.251	0.025	0.019	060500	-0.150	0.001	-0.007
060244	0.357	0.014	0.028	060502	0.189	-0.020	0.005
060246	-0.045	0.018	0.016	060504	-0.015	-0.005	0.008
060248	0.794	0.049	0.032	060506	0.251	-0.028	0.014
060251	0.082	0.062	0.016	060509	0.097	0.027	0.043
060253	0.024	0.065	-0.010	060511	0.307	0.050	0.019
060255	0.093	0.031	0.017	060513	0.005	-0.019	0.005
060258	0.180	0.014	0.015	060516	0.016	0.000	0.036
060300	0.232	-0.004	0.034	060518	0.039	0.006	0.002
060302	0.073	-0.012	0.022	060520	0.199	0.017	-0.010
060305	0.383	0.001	0.013	060523	0.117	0.004	-0.021
060307	0.050	0.054	0.007	060525	-0.054	0.010	-0.008
060309	0.098	0.024	0.005	060527	0.212	0.041	-0.006
060311	0.006	0.047	0.036	060529	0.220	0.002	-0.008
060314	0.574	0.007	0.014	060532	0.023	0.032	-0.016
060316	0.386	0.034	0.027	060534	0.106	-0.028	-0.014
060318	0.111	0.029	0.026	060536	0.139	-0.020	-0.005
060321	0.069	0.040	0.038	060539	0.384	-0.034	-0.008
060323	0.405	0.060	0.032	060541	0.298	-0.014	-0.006
060325	0.108	0.009	0.022	060543	0.119	0.001	-0.014
060328	0.243	0.031	0.013	060546	0.092	-0.008	-0.023
060330	0.354	0.048	0.026	060548	-0.033	-0.008	0.016
060332	0.668	0.046	0.037	060550	-0.156	-0.006	-0.009
060334	0.002	0.034	0.044	060552	0.137	0.015	-0.006
060337	0.026	0.024	0.013	060555	0.143	0.008	-0.010
060339	0.174	0.069	0.025	060557	0.341	-0.003	-0.004
060341	0.145	0.038	0.020	060559	-0.110	-0.008	0.006
060344	-0.013	0.023	0.003	060602	0.457	0.000	-0.020
060346	-0.060	0.023	-0.020	060604	0.186	0.013	-0.031
060348	0.268	0.002	-0.005	060606	-0.092	0.009	-0.008
060351	0.114	0.006	-0.009	060609	0.334	-0.014	-0.004
060353	0.697	0.051	-0.008	060611	0.238	-0.027	-0.022
060355	0.163	0.027	-0.010	060613	0.180	-0.006	-0.016
060357	0.088	-0.013	-0.003	060615	0.083	-0.002	-0.014
060400	0.308	-0.018	0.005	060618	0.186	-0.010	-0.007
060402	0.139	-0.031	0.005	060620	0.048	-0.025	0.001
060404	0.252	0.018	-0.007	060622	-0.005	-0.028	0.036
060407	0.244	0.033	-0.001	060625	-0.039	-0.017	-0.003
060409	0.292	0.030	0.010	060627	0.174	-0.013	-0.002
060411	-0.076	0.055	0.023	060629	-0.094	-0.001	-0.001
060414	-0.000	0.030	0.024	060632	-0.042	0.000	0.012
060416	0.102	0.020	0.002	060634	-0.058	-0.007	0.007
060418	0.341	0.059	0.080	060636	0.157	0.003	-0.017
060420	0.080	0.054	0.007	060638	-0.025	0.038	-0.036
060423	0.143	0.025	-0.003	060641	0.092	0.007	-0.028
060425	0.076	0.016	0.017	060643	-0.042	-0.015	-0.024
060427	0.124	-0.009	-0.002	060645	0.100	0.019	-0.005
060430	0.027	-0.019	0.008	060648	0.134	-0.013	0.003
060432	0.022	-0.023	-0.004	060650	0.050	-0.012	-0.016
060434	0.057	0.021	0.009	060652	-0.088	0.018	0.000
060437	0.120	0.004	0.001	060655	0.170	-0.012	-0.012
060439	-0.023	-0.008	0.005	060657	0.108	0.027	0.025
060441	1.217	-0.015	-0.010	060659	0.054	-0.016	-0.010
060443	0.515	0.006	-0.004	060701	0.181	-0.039	-0.017
060446	0.093	-0.014	0.009	060704	-0.030	-0.036	-0.017
060448	0.081	0.014	0.008	060706	0.040	-0.039	-0.012
060450	0.265	0.035	0.018	060708	0.154	0.000	-0.029
060453	0.223	-0.026	-0.006	060711	0.005	0.009	-0.025

APPENDIX 2 - CONTINUED

EV LAC AUG 26, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
060713	-0.048	-0.023	-0.044	060738	-0.118	-0.010	-0.010
060715	0.145	-0.028	-0.019	060741	0.300	-0.002	-0.006
060718	-0.116	-0.008	-0.011	060743	0.151	0.006	0.006
060720	-0.138	-0.020	-0.013	060745	0.156	-0.009	-0.010
060722	0.042	-0.010	-0.025	060747	0.219	0.030	0.009
060724	-0.137	-0.004	-0.015	060750	0.259	-0.010	-0.006
060727	0.128	0.026	-0.029	060752	0.556	-0.006	0.006
060729	0.240	0.000	-0.029	060754	0.144	0.012	-0.024
060731	-0.161	-0.041	-0.037	060757	0.397	-0.009	-0.021
060734	-0.020	-0.038	-0.008	060759	0.236	-0.007	-0.011
060736	-0.187	-0.027	-0.028				

APPENDIX 2 - CONTINUED

EV LAC SEP 3, 1973

TIME	U	B	R	TIME	U	B	R
072351	0.143	0.011	0.016	072709	0.297	0.010	-0.015
072354	-0.002	0.005	0.014	072712	0.298	0.031	0.016
072358	-0.102	0.006	0.007	072716	0.066	0.039	-0.001
072401	0.086	0.053	0.016	072719	0.433	0.055	0.008
072404	0.044	0.024	0.007	072722	0.120	0.039	-0.018
072408	-0.015	0.017	0.011	072726	0.281	0.013	-0.011
072411	0.062	0.014	-0.007	072729	0.210	0.036	-0.007
072414	-0.056	-0.011	0.010	072732	0.449	0.014	0.000
072418	0.023	-0.012	0.012	072736	0.246	0.074	0.001
072421	-0.128	0.012	0.000	072739	0.125	0.032	-0.010
072424	0.030	0.022	0.005	072742	0.282	0.025	-0.008
072427	-0.170	0.022	0.027	072745	0.053	0.041	0.002
072431	-0.005	0.030	0.009	072749	0.229	0.003	-0.012
072434	-0.078	0.013	0.016	072752	0.115	-0.008	-0.018
072437	0.013	0.055	0.008	072755	0.188	0.007	-0.014
072441	0.291	0.050	0.014	072759	0.113	-0.005	-0.007
072444	0.195	0.093	0.040	072802	0.196	-0.019	-0.019
072447	0.306	0.127	0.060	072805	0.235	0.003	-0.025
072451	0.909	0.100	0.042	072809	-0.064	-0.030	-0.035
072454	0.803	0.119	0.058	072812	0.244	-0.006	-0.011
072457	0.719	0.131	0.043	072815	0.197	0.021	-0.038
072500	0.740	0.121	0.040	072850	0.173	-0.022	-0.003
072504	0.491	0.089	0.038	072854	0.428	0.042	0.002
072507	0.339	0.075	0.017	072857	0.119	-0.003	-0.004
072510	0.837	0.080	0.018	072900	0.262	-0.019	0.027
072514	0.408	0.085	0.024	072903	0.291	0.010	-0.002
072517	0.383	0.049	0.017	072907	0.237	0.009	0.007
072520	0.441	0.055	0.048	072910	0.128	0.013	-0.004
072524	0.369	0.064	0.036	072913	0.375	0.022	0.019
072527	0.678	0.078	0.032	072917	0.029	0.014	0.014
072530	0.857	0.090	0.031	072920	0.119	0.054	-0.002
072533	0.390	0.077	0.028	072923	0.260	-0.005	0.019
072537	0.549	0.107	0.024	072927	0.133	0.021	-0.011
072540	0.712	0.091	0.024	072930	-0.034	0.014	-0.004
072543	0.455	0.066	0.030	072933	0.163	-0.005	-0.001
072547	0.460	0.077	0.015	072936	0.203	0.054	-0.004
072550	0.404	0.054	0.022	072940	0.307	-0.004	0.007
072553	0.511	0.085	0.023	072943	0.209	-0.017	-0.010
072557	0.469	0.053	0.053	072946	0.109	0.015	0.006
072600	0.702	0.059	0.016	072950	-0.013	0.021	0.004
072603	0.217	0.093	0.021	072953	0.133	0.008	0.012
072606	0.274	0.092	0.012	072956	0.107	0.032	0.005
072610	0.482	0.086	0.000	073000	0.143	0.066	0.090
072613	0.158	0.096	0.017	073003	0.330	0.058	0.093
072616	0.379	0.057	0.031	073006	0.225	0.102	0.092
072620	0.271	0.047	0.013	073009	0.143	0.074	0.073
072623	0.269	0.063	0.002	073013	0.168	-0.007	0.080
072626	0.389	0.069	0.019	073016	0.119	0.056	0.060
072630	0.254	0.066	0.023	073019	0.243	0.029	0.085
072633	0.126	0.035	0.019	073023	0.003	0.007	0.001
072636	0.425	0.030	0.008	073026	0.101	0.010	0.014
072639	0.512	0.023	-0.005	073029	-0.052	0.009	0.004
072643	0.160	-0.002	0.011	073033	0.074	-0.010	-0.008
072646	0.306	0.036	-0.006	073036	-0.016	-0.033	0.008
072649	0.243	0.071	0.004	073039	0.020	0.028	-0.007
072653	0.084	0.044	0.013	073042	0.094	0.012	-0.003
072656	0.229	0.019	-0.010	073046	0.103	0.009	0.001
072659	0.268	0.017	0.002	073049	0.141	0.043	0.024
072703	0.251	0.050	-0.011	073052	0.102	-0.016	0.003
072706	0.106	0.023	0.012	073056	0.346	0.004	0.004

APPENDIX 2 - CONTINUED

EV LAC SEP 3, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
073059	0.185	-0.015	-0.006	073314	-0.029	-0.005	-0.017
073102	0.078	0.003	0.002	073318	0.193	-0.057	-0.005
073106	0.189	0.006	0.018	073321	-0.063	-0.012	-0.010
073109	-0.024	0.012	-0.001	073324	-0.103	-0.015	0.003
073112	-0.083	-0.016	0.003	073327	0.322	-0.033	-0.012
073115	0.152	-0.004	0.009	073331	-0.131	-0.028	0.003
073119	0.212	-0.004	0.010	073334	0.041	-0.051	-0.012
073122	-0.117	0.051	0.016	073337	0.117	-0.018	-0.001
073125	-0.001	-0.029	-0.008	073341	0.129	-0.031	-0.012
073129	0.228	-0.004	-0.000	073344	0.142	-0.043	-0.023
073132	0.120	0.002	0.004	073347	0.022	-0.016	-0.007
073135	0.227	-0.013	-0.005	073351	-0.093	-0.009	-0.034
073139	0.160	-0.003	-0.014	073354	0.053	-0.032	-0.004
073142	-0.029	-0.005	-0.009	073357	-0.029	-0.023	-0.006
073145	0.059	-0.013	-0.001	073400	0.229	-0.030	-0.027
073148	0.131	-0.013	-0.015	073404	-0.222	-0.015	-0.011
073152	-0.010	0.006	0.028	073407	0.055	-0.022	-0.010
073155	0.103	-0.021	0.019	073410	0.016	-0.027	-0.025
073158	0.030	-0.007	0.010	073414	-0.054	-0.022	-0.013
073202	0.164	-0.008	-0.005	073417	0.121	-0.026	0.007
073205	0.011	0.006	0.010	073420	0.086	-0.017	-0.020
073208	-0.024	-0.027	-0.001	073424	0.095	-0.053	-0.025
073212	0.021	-0.017	0.011	073427	0.241	-0.010	0.007
073215	0.157	0.008	0.014	073430	-0.053	0.007	-0.027
073218	-0.019	-0.011	0.027	073433	-0.003	-0.023	-0.020
073221	0.185	-0.012	0.001	073437	0.087	-0.032	-0.021
073225	0.036	0.010	0.003	073440	0.048	-0.013	-0.008
073228	0.136	0.012	0.008	073443	-0.040	-0.028	-0.026
073231	0.049	-0.022	0.013	073447	0.040	-0.045	-0.029
073235	0.060	-0.002	0.009	073450	0.067	-0.010	-0.037
073238	0.052	-0.022	0.026	073453	0.076	-0.046	-0.009
073241	-0.133	-0.009	0.043	073457	0.029	-0.063	-0.027
073245	0.082	-0.031	0.053	073500	-0.031	-0.003	-0.029
073248	-0.008	-0.012	0.080	073503	-0.090	-0.058	-0.009
073251	-0.089	0.018	0.064	073506	-0.032	-0.011	-0.019
073254	0.026	-0.017	0.005	073510	0.076	-0.007	-0.017
073258	0.044	-0.065	-0.006	073513	-0.021	0.008	0.056
073301	0.175	0.019	-0.013	073516	0.040	-0.007	0.027
073304	0.120	-0.041	-0.018	073520	0.011	-0.048	0.011
073308	-0.011	-0.000	-0.006	073523	-0.147	-0.020	-0.035
073311	-0.037	-0.029	-0.017	073526	0.086	-0.028	-0.035

APPENDIX 2 - CONTINUED

FV LAC OCT 7, 1973

TIME	U	B	R	TIME	U	B	R
020016	0.032	0.000	0.025	020234	1.451	0.000	0.101
020018	0.220	0.000	0.015	020236	1.161	0.000	0.062
020021	0.349	0.000	0.033	020239	1.169	0.000	0.085
020023	0.252	0.000	0.011	020241	1.159	0.000	0.094
020025	0.402	0.000	0.044	020243	1.333	0.000	0.098
020028	0.248	0.000	0.036	020246	1.052	0.000	0.076
020030	0.675	0.000	0.038	020248	1.111	0.000	0.088
020032	0.250	0.000	0.048	020250	1.121	0.000	0.087
020035	0.492	0.000	0.050	020253	0.843	0.000	0.072
020037	0.364	0.000	0.042	020255	0.906	0.000	0.079
020039	1.034	0.000	0.040	020257	0.799	0.000	0.078
020041	0.468	0.000	0.071	020259	0.637	0.000	0.075
020044	0.825	0.000	0.052	020302	0.963	0.000	0.056
020046	1.068	0.000	0.068	020304	0.794	0.000	0.082
020048	1.213	0.000	0.073	020306	0.850	0.000	0.063
020051	1.585	0.000	0.094	020309	0.667	0.000	0.082
020053	1.391	0.000	0.085	020311	0.703	0.000	0.066
020055	1.757	0.000	0.108	020313	1.137	0.000	0.078
020058	1.724	0.000	0.118	020316	1.252	0.000	0.070
020100	1.668	0.000	0.124	020318	0.885	0.000	0.084
020102	1.956	0.000	0.141	020320	1.004	0.000	0.087
020104	1.917	0.000	0.127	020322	0.945	0.000	0.077
020107	2.028	0.000	0.132	020325	1.230	0.000	0.089
020109	1.871	0.000	0.117	020327	1.024	0.000	0.081
020111	1.711	0.000	0.116	020329	0.783	0.000	0.100
020114	1.345	0.000	0.119	020332	1.181	0.000	0.101
020116	1.450	0.000	0.081	020334	1.463	0.000	0.119
020118	0.659	0.000	0.097	020336	1.658	0.000	0.121
020121	0.888	0.000	0.091	020339	2.052	0.000	0.132
020123	1.078	0.000	0.072	020341	1.676	0.000	0.123
020125	1.018	0.000	0.072	020343	1.610	0.000	0.113
020127	1.196	0.000	0.093	020345	2.118	0.000	0.122
020130	0.959	0.000	0.067	020348	1.738	0.000	0.126
020132	0.890	0.000	0.065	020350	1.712	0.000	0.120
020134	1.028	0.000	0.051	020352	1.647	0.000	0.129
020137	0.918	0.000	0.065	020355	1.645	0.000	0.134
020139	0.537	0.000	0.058	020357	1.976	0.000	0.138
020141	0.687	0.000	0.051	020359	2.234	0.000	0.158
020144	0.975	0.000	0.059	020402	2.288	0.000	0.164
020146	0.732	0.000	0.052	020404	2.944	0.000	0.168
020148	0.951	0.000	0.058	020406	2.976	0.000	0.159
020150	0.705	0.000	0.068	020408	2.371	0.000	0.180
020153	0.614	0.000	0.051	020411	2.595	0.000	0.180
020155	0.598	0.000	0.067	020413	2.712	0.000	0.188
020157	0.744	0.000	0.050	020415	2.084	0.000	0.197
020200	0.705	0.000	0.051	020418	3.350	0.000	0.211
020202	0.762	0.000	0.068	020420	2.534	0.000	0.181
020204	0.604	0.000	0.051	020422	2.875	0.000	0.219
020207	0.523	0.000	0.081	020425	3.117	0.000	0.195
020209	1.127	0.000	0.053	020427	2.254	0.000	0.190
020211	0.909	0.000	0.070	020429	3.197	0.000	0.203
020213	1.112	0.000	0.051	020431	3.126	0.000	0.200
020216	0.765	0.000	0.052	020434	2.869	0.000	0.199
020218	0.994	0.000	0.071	020436	2.894	0.000	0.191
020220	0.985	0.000	0.072	020438	2.824	0.000	0.211
020223	1.368	0.000	0.085	020441	3.651	0.000	0.225
020225	1.233	0.000	0.097	020443	3.601	0.000	0.219
020227	1.078	0.000	0.091	020445	3.528	0.000	0.219
020230	1.358	0.000	0.073	020448	3.486	0.000	0.228
020232	1.182	0.000	0.079	020450	3.081	0.000	0.213

APPENDIX 2 - CONTINUED

EV LAC OCT 7, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
020452	2.714	0.000	0.197	020649	0.574	0.000	0.075
020454	2.733	0.000	0.209	020651	1.384	0.000	0.079
020457	2.514	0.000	0.172	020652	1.202	0.000	0.064
020459	2.318	0.000	0.187	020653	1.080	0.000	0.094
020501	2.378	0.000	0.179	020657	0.884	0.000	0.098
020504	2.332	0.000	0.182	020659	0.991	0.000	0.080
020506	1.755	0.000	0.185	020701	0.964	0.000	0.084
020508	2.456	0.000	0.183	020704	1.001	0.000	0.092
020511	2.225	0.000	0.170	020705	1.102	0.000	0.088
020513	2.424	0.000	0.182	020706	0.626	0.000	0.090
020515	2.085	0.000	0.156	020707	0.874	0.000	0.077
020517	1.839	0.000	0.150	020708	0.640	0.000	0.078
020520	1.802	0.000	0.165	020711	0.890	0.000	0.057
020522	1.731	0.000	0.168	020712	0.867	0.000	0.072
020524	2.019	0.000	0.161	020714	0.585	0.000	0.085
020525	2.009	0.000	0.159	020716	0.705	0.000	0.057
020528	1.660	0.000	0.149	020719	0.759	0.000	0.103
020530	1.809	0.000	0.173	020720	0.740	0.000	0.056
020532	1.757	0.000	0.140	020722	0.876	0.000	0.063
020535	1.522	0.000	0.138	020723	0.859	0.000	0.081
020537	1.502	0.000	0.135	020727	0.834	0.000	0.074
020538	1.359	0.000	0.131	020729	0.638	0.000	0.070
020539	1.344	0.000	0.140	020730	0.982	0.000	0.050
020540	1.572	0.000	0.112	020735	0.821	0.000	0.063
020541	1.190	0.000	0.093	020736	0.994	0.000	0.052
020542	1.404	0.000	0.115	020738	0.932	0.000	0.066
020544	1.879	0.000	0.116	020739	0.831	0.000	0.072
020545	1.139	0.000	0.106	020744	0.875	0.000	0.064
020547	1.842	0.000	0.124	020745	1.369	0.000	0.081
020550	1.171	0.000	0.094	020746	0.856	0.000	0.052
020552	1.658	0.000	0.110	020751	0.681	0.000	0.067
020553	1.299	0.000	0.100	020753	0.714	0.000	0.078
020555	1.016	0.000	0.087	020754	0.513	0.000	0.076
020557	0.760	0.000	0.103	020756	0.717	0.000	0.079
020600	1.023	0.000	0.112	020758	0.734	0.000	0.071
020602	0.993	0.000	0.108	020759	0.451	0.000	0.062
020603	1.280	0.000	0.100	020803	0.347	0.000	0.067
020606	1.023	0.000	0.106	020805	0.770	0.000	0.070
020608	1.199	0.000	0.091	020807	0.804	0.000	0.065
020610	1.384	0.000	0.077	020810	0.799	0.000	0.074
020611	1.156	0.000	0.108	020812	0.939	0.000	0.053
020614	0.769	0.000	0.073	020814	0.672	0.000	0.057
020615	1.129	0.000	0.080	020815	0.462	0.000	0.081
020617	1.019	0.000	0.101	020817	0.831	0.000	0.066
020618	1.533	0.000	0.090	020819	0.732	0.000	0.069
020620	0.762	0.000	0.100	020821	0.654	0.000	0.075
020623	0.950	0.000	0.082	020823	0.735	0.000	0.068
020625	1.113	0.000	0.092	020826	0.982	0.000	0.053
020627	0.805	0.000	0.085	020827	1.061	0.000	0.080
020630	1.046	0.000	0.067	020828	0.958	0.000	0.048
020632	0.832	0.000	0.081	020829	1.024	0.000	0.091
020633	0.887	0.000	0.088	020833	1.011	0.000	0.051
020634	1.058	0.000	0.098	020836	0.770	0.000	0.062
020635	0.763	0.000	0.114	020838	0.935	0.000	0.065
020638	0.975	0.000	0.074	020840	1.005	0.000	0.060
020640	0.663	0.000	0.087	020842	0.818	0.000	0.083
020642	1.009	0.000	0.092	020845	0.784	0.000	0.067
020644	0.930	0.000	0.065	020847	0.815	0.000	0.063
020647	1.099	0.000	0.083	020849	0.453	0.000	0.045
020648	0.892	0.000	0.075	020852	0.555	0.000	0.051

APPENDIX 2 - CONTINUED

EV LAC OCT 7, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
020854	0.784	0.000	0.066	021104	0.746	0.000	0.058
020856	0.711	0.000	0.067	021106	0.574	0.000	0.060
020857	0.957	0.000	0.075	021108	0.833	0.000	0.045
020858	0.510	0.000	0.064	021111	0.540	0.000	0.047
020903	1.054	0.000	0.069	021113	0.524	0.000	0.040
020905	0.648	0.000	0.065	021115	0.560	0.000	0.059
020907	0.647	0.000	0.057	021118	0.239	0.000	0.052
020909	1.064	0.000	0.064	021120	0.482	0.000	0.052
020912	1.085	0.000	0.056	021122	0.672	0.000	0.043
020913	0.902	0.000	0.049	021125	0.371	0.000	0.039
020914	0.789	0.000	0.067	021127	0.565	0.000	0.036
020918	0.685	0.000	0.073	021129	0.752	0.000	0.060
020920	0.482	0.000	0.062	021131	0.891	0.000	0.048
020923	0.576	0.000	0.067	021134	0.673	0.000	0.046
020925	0.863	0.000	0.080	021136	0.445	0.000	0.040
020927	0.606	0.000	0.045	021138	0.563	0.000	0.048
020930	0.678	0.000	0.068	021141	0.452	0.000	0.070
020932	0.526	0.000	0.059	021143	0.552	0.000	0.061
020934	0.632	0.000	0.056	021145	0.715	0.000	0.038
020936	0.674	0.000	0.056	021148	0.260	0.000	0.042
020939	0.632	0.000	0.063	021150	0.183	0.000	0.057
020941	0.614	0.000	0.070	021152	0.567	0.000	0.054
020943	0.788	0.000	0.040	021154	0.501	0.000	0.037
020946	0.553	0.000	0.071	021157	0.709	0.000	0.067
020947	0.510	0.000	0.087	021159	0.697	0.000	0.038
020949	0.587	0.000	0.056	021201	0.577	0.000	0.068
020951	0.795	0.000	0.041	021204	0.503	0.000	0.046
020954	0.610	0.000	0.066	021205	0.254	0.000	0.071
020956	0.405	0.000	0.048	021207	0.693	0.000	0.052
020958	0.670	0.000	0.063	021209	0.292	0.000	0.060
021001	0.593	0.000	0.079	021212	0.550	0.000	0.053
021003	0.544	0.000	0.064	021214	0.669	0.000	0.047
021004	0.869	0.000	0.081	021216	0.637	0.000	0.047
021006	0.628	0.000	0.050	021219	0.664	0.000	0.041
021009	0.738	0.000	0.057	021221	0.238	0.000	0.030
021010	0.731	0.000	0.081	021222	0.406	0.000	0.052
021011	0.518	0.000	0.060	021224	0.521	0.000	0.031
021013	0.949	0.000	0.053	021227	0.467	0.000	0.055
021016	0.406	0.000	0.054	021229	0.523	0.000	0.056
021018	0.502	0.000	0.045	021231	0.524	0.000	0.048
021020	0.862	0.000	0.068	021232	0.286	0.000	0.068
021023	0.535	0.000	0.074	021233	0.300	0.000	0.042
021025	0.467	0.000	0.057	021236	0.349	0.000	0.060
021027	0.392	0.000	0.063	021238	0.468	0.000	0.052
021029	0.560	0.000	0.040	021240	0.632	0.000	0.061
021032	0.900	0.000	0.073	021243	0.845	0.000	0.059
021034	0.710	0.000	0.072	021245	0.534	0.000	0.041
021036	0.336	0.000	0.057	021247	0.192	0.000	0.047
021039	0.414	0.000	0.074	021249	0.419	0.000	0.032
021041	0.944	0.000	0.032	021252	0.502	0.000	0.056
021043	0.530	0.000	0.044	021254	0.565	0.000	0.030
021046	0.394	0.000	0.060	021256	0.428	0.000	0.022
021048	0.621	0.000	0.060	021259	0.496	0.000	0.020
021049	0.436	0.000	0.080	021301	0.579	0.000	0.057
021050	0.867	0.000	0.059	021303	0.633	0.000	0.038
021052	0.266	0.000	0.049	021306	0.401	0.000	0.043
021055	0.659	0.000	0.059	021308	0.466	0.000	0.045
021057	1.011	0.000	0.070	021310	0.421	0.000	0.054
021059	0.613	0.000	0.067	021312	0.910	0.000	0.033
021102	0.495	0.000	0.048	021315	0.276	0.000	0.033

APPENDIX 2 - CONTINUED

EV LAC OCT 7, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
021317	0.184	0.000	0.023	021525	0.385	0.000	0.018
021319	0.736	0.000	0.061	021527	0.294	0.000	0.029
021322	0.465	0.000	0.030	021529	0.417	0.000	0.029
021324	0.411	0.000	0.033	021532	0.381	0.000	0.025
021326	0.171	0.000	0.028	021534	0.443	0.000	0.028
021329	0.297	0.000	0.043	021536	0.479	0.000	0.026
021331	0.546	0.000	0.047	021539	0.382	0.000	0.031
021333	0.564	0.000	0.049	021541	0.478	0.000	0.027
021335	0.576	0.000	0.031	021543	0.298	0.000	0.019
021338	0.443	0.000	0.041	021545	0.355	0.000	0.022
021340	0.401	0.000	0.052	021548	0.359	0.000	0.028
021342	0.641	0.000	0.045	021550	0.515	0.000	0.024
021345	0.262	0.000	0.034	021552	0.410	0.000	0.032
021347	0.437	0.000	0.027	021555	0.470	0.000	0.022
021349	0.480	0.000	0.049	021557	0.495	0.000	0.015
021350	0.265	0.000	0.026	021559	0.040	0.000	0.016
021353	0.695	0.000	0.042	021602	0.273	0.000	0.028
021355	0.614	0.000	0.022	021604	0.437	0.000	0.016
021357	0.578	0.000	0.040	021606	0.243	0.000	0.039
021400	0.484	0.000	0.043	021608	0.406	0.000	0.012
021401	0.485	0.000	0.019	021610	0.650	0.000	0.035
021402	0.444	0.000	0.057	021612	0.204	0.000	0.029
021403	0.420	0.000	0.039	021614	0.312	0.000	0.041
021404	0.410	0.000	0.031	021616	0.362	0.000	0.034
021407	0.354	0.000	0.038	021618	0.622	0.000	0.034
021410	0.619	0.000	0.029	021619	0.355	0.000	0.035
021412	0.171	0.000	0.040	021623	0.291	0.000	0.023
021414	0.276	0.000	0.042	021624	0.198	0.000	0.008
021417	0.541	0.000	0.032	021627	0.397	0.000	0.012
021419	0.440	0.000	0.037	021629	0.509	0.000	0.027
021421	0.651	0.000	0.029	021631	0.548	0.000	0.026
021423	0.389	0.000	0.026	021634	0.132	0.000	0.027
021425	0.141	0.000	0.049	021635	-0.108	0.000	0.007
021427	0.339	0.000	0.022	021637	0.451	0.000	0.021
021429	0.275	0.000	0.018	021639	0.319	0.000	0.023
021431	0.307	0.000	0.018	021642	0.138	0.000	0.019
021434	0.165	0.000	0.030	021644	0.574	0.000	0.025
021436	0.338	0.000	0.047	021646	0.452	0.000	0.039
021438	0.226	0.000	0.037	021647	0.539	0.000	0.042
021441	0.314	0.000	0.034	021648	0.257	0.000	0.030
021443	0.453	0.000	0.034	021651	0.324	0.000	0.040
021445	0.413	0.000	0.034	021652	0.366	0.000	0.024
021448	0.184	0.000	0.029	021653	0.544	0.000	-0.003
021449	0.491	0.000	0.034	021656	0.682	0.000	0.020
021450	0.360	0.000	0.018	021657	0.557	0.000	0.034
021451	0.459	0.000	0.056	021659	0.422	0.000	0.032
021455	0.561	0.000	0.052	021700	0.514	0.000	0.063
021457	0.439	0.000	0.031	021702	0.280	0.000	0.038
021500	0.788	0.000	0.028	021705	0.543	0.000	0.041
021502	0.458	0.000	0.026	021707	0.415	0.000	0.028
021504	0.605	0.000	0.019	021709	0.223	0.000	0.036
021506	0.142	0.000	0.019	021710	0.635	0.000	0.047
021508	0.258	0.000	0.037	021713	0.048	0.000	0.054
021510	0.176	0.000	0.024	021714	0.406	0.000	0.030
021512	0.498	0.000	0.027	021715	0.614	0.000	0.039
021514	0.362	0.000	0.037	021716	0.286	0.000	0.019
021517	0.481	0.000	0.032	021717	0.317	0.000	0.023
021519	0.207	0.000	0.030	021718	0.295	0.000	0.031
021521	0.042	0.000	0.054	021719	0.023	0.000	0.011
021524	0.632	0.000	0.038	021720	0.148	0.000	0.037

APPENDIX 2 - CONTINUED

EV LAC OCT 7, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
021724	0.471	0.000	0.040	021839	0.450	0.000	0.041
021726	0.299	0.000	0.031	021840	0.419	0.000	0.017
021728	0.355	0.000	0.024	021842	0.086	0.000	0.034
021729	0.342	0.000	0.032	021845	0.317	0.000	0.041
021730	0.197	0.000	0.035	021847	0.294	0.000	0.026
021733	0.163	0.000	0.017	021848	0.286	0.000	0.024
021735	0.336	0.000	0.021	021849	0.309	0.000	0.034
021736	0.087	0.000	0.034	021850	0.138	0.000	0.030
021737	0.334	0.000	0.025	021854	0.017	0.000	0.032
021738	0.240	0.000	0.049	021856	-0.044	0.000	0.037
021739	0.965	0.000	0.026	021858	0.317	0.000	0.032
021740	0.335	0.000	0.040	021901	0.091	0.000	0.018
021744	0.075	0.000	0.022	021903	0.209	0.000	0.021
021746	0.259	0.000	0.024	021905	0.332	0.000	0.014
021747	0.433	0.000	0.036	021906	0.247	0.000	0.010
021748	-0.105	0.000	0.040	021907	0.200	0.000	0.027
021750	0.232	0.000	0.032	021909	0.124	0.000	0.027
021753	-0.049	0.000	0.036	021910	0.070	0.000	0.029
021755	0.163	0.000	0.035	021911	-0.274	0.000	-0.005
021756	0.101	0.000	0.058	021913	0.055	0.000	0.017
021758	0.158	0.000	0.033	021914	0.113	0.000	0.017
021800	0.041	0.000	0.027	021916	0.047	0.000	0.008
021802	0.271	0.000	0.037	021919	0.209	0.000	0.012
021804	0.224	0.000	0.026	021921	0.426	0.000	0.008
021805	0.089	0.000	0.011	021922	-0.087	0.000	-0.001
021806	-0.278	0.000	0.056	021923	0.036	0.000	0.014
021807	0.439	0.000	0.036	021924	0.253	0.000	0.001
021810	0.250	0.000	0.029	021925	0.302	0.000	-0.005
021812	0.283	0.000	0.031	021927	0.177	0.000	0.012
021813	0.323	0.000	0.032	021930	0.029	0.000	0.022
021814	0.706	0.000	0.026	021932	-0.008	0.000	-0.017
021817	0.491	0.000	0.015	021933	0.610	0.000	0.004
021818	0.395	0.000	0.027	021934	0.343	0.000	-0.023
021819	0.246	0.000	0.035	021935	0.062	0.000	0.025
021820	0.172	0.000	0.015	021938	0.350	0.000	0.006
021821	0.223	0.000	0.040	021940	0.138	0.000	0.007
021824	0.364	0.000	0.027	021943	0.348	0.000	-0.006
021825	0.138	0.000	0.013	021944	0.123	0.000	0.011
021826	0.475	0.000	0.036	021945	0.732	0.000	0.012
021827	0.081	0.000	0.042	021948	0.308	0.000	-0.008
021828	0.379	0.000	0.018	021949	-0.006	0.000	0.009
021829	0.212	0.000	0.056	021950	0.458	0.000	-0.019
021832	0.215	0.000	0.016	021951	-0.063	0.000	-0.004
021833	-0.034	0.000	0.024	021955	0.180	0.000	-0.004
021834	0.069	0.000	0.016	021957	0.047	0.000	-0.001
021838	0.320	0.000	0.028	021959	0.371	0.000	-0.003

APPENDIX 2 - CONTINUED

FV LAC OCT 9, 1973

TIME	U	B	R	TIME	U	B	R
040401	0.078	-0.008	-0.038	040619	0.273	0.024	-0.061
040403	-0.246	0.046	-0.041	040621	0.211	0.018	-0.077
040406	0.070	0.065	-0.011	040624	0.206	0.024	-0.024
040408	0.334	0.063	-0.003	040626	0.174	-0.007	-0.148
040410	0.448	0.064	0.006	040628	0.130	0.037	-0.146
040412	0.251	0.027	-0.097	040630	0.702	0.084	-0.187
040415	0.233	0.108	-0.151	040633	0.402	0.104	-0.150
040417	0.275	0.104	-0.111	040635	0.491	0.125	-0.130
040419	0.249	0.200	-0.069	040637	0.820	0.153	-0.158
040422	0.020	0.234	-0.019	040640	0.168	0.090	-0.085
040424	0.740	0.232	-0.005	040642	-0.023	0.067	-0.110
040426	0.528	0.365	0.045	040644	0.424	0.048	-0.112
040429	1.137	0.538	0.137	040647	0.019	0.086	-0.056
040431	0.788	0.623	0.172	040649	0.235	0.044	-0.015
040433	1.165	0.621	0.180	040651	0.714	0.107	0.007
040435	1.142	0.689	0.196	040653	0.308	0.054	0.010
040438	0.907	0.664	0.205	040656	0.573	0.055	0.029
040440	0.983	0.687	0.211	040658	0.330	0.020	0.008
040442	1.026	0.651	0.253	040700	0.391	0.018	-0.021
040445	1.789	0.772	0.289	040703	0.209	-0.014	-0.013
040447	1.165	0.866	0.320	040705	-0.170	0.055	-0.028
040449	0.809	0.871	0.381	040707	0.268	0.012	-0.030
040452	1.308	0.953	0.428	040710	0.171	-0.035	-0.022
040454	1.365	0.938	0.422	040712	0.465	0.023	-0.022
040456	0.738	0.963	0.404	040714	0.325	-0.002	-0.027
040458	1.209	0.869	0.391	040716	0.183	-0.034	-0.025
040501	1.182	0.935	0.384	040719	-0.313	0.001	-0.003
040503	0.958	0.871	0.369	040721	-0.106	0.046	-0.016
040505	1.377	0.789	0.325	040723	0.291	-0.003	-0.008
040508	0.891	0.754	0.298	040726	0.655	0.016	-0.026
040510	0.779	0.665	0.242	040728	0.038	0.034	-0.012
040512	1.258	0.608	0.198	040730	-0.102	-0.021	-0.024
040515	0.451	0.518	0.106	040733	0.071	0.043	-0.010
040517	0.616	0.500	0.138	040735	-0.026	0.004	-0.008
040519	0.629	0.544	0.152	041131	0.181	-0.032	0.020
040521	0.770	0.500	0.098	041133	0.138	-0.020	0.016
040524	0.280	0.450	0.068	041136	0.114	0.038	0.006
040526	0.663	0.354	0.060	041138	0.000	0.014	0.014
040528	0.651	0.360	0.042	041140	0.079	0.014	0.010
040531	0.735	0.462	0.034	041143	0.102	0.019	0.002
040533	0.752	0.363	0.033	041145	0.131	-0.013	0.008
040535	0.556	0.428	0.063	041147	0.086	0.079	0.021
040538	1.217	0.495	0.074	041149	0.387	-0.001	0.008
040540	0.773	0.553	0.113	041152	0.143	0.036	0.037
040542	0.631	0.295	-0.007	041154	0.502	-0.009	0.009
040544	0.371	0.194	-0.064	041156	0.542	0.010	0.009
040547	0.013	0.141	-0.071	041159	0.299	0.007	0.029
040549	-0.035	0.134	-0.071	041201	-0.012	0.056	0.027
040551	0.471	0.192	-0.077	041203	0.713	0.000	0.018
040554	0.361	0.161	-0.135	041206	0.441	0.070	0.025
040556	-0.126	0.070	-0.117	041208	0.554	0.104	0.044
040558	0.149	0.124	-0.038	041210	0.596	0.073	0.072
040601	0.114	0.103	0.015	041212	0.720	0.068	0.057
040603	-0.266	0.109	0.025	041215	0.735	0.115	0.058
040605	0.276	0.061	0.041	041217	0.683	0.081	0.051
040607	0.192	0.119	0.032	041219	1.021	0.045	0.063
040610	0.237	0.046	0.004	041222	0.655	0.157	0.045
040612	0.139	0.028	0.003	041224	0.699	0.164	0.081
040614	0.069	0.036	-0.013	041226	1.085	0.065	0.051
040617	0.074	0.007	-0.012	041229	0.834	0.119	0.069

APPENDIX 2 - CONTINUED

EV LAC OCT 9, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
041231	0.816	0.104	0.059	041449	1.104	0.135	0.028
041233	0.565	0.089	0.047	041451	1.087	0.101	0.057
041235	0.596	0.071	0.071	041453	0.464	0.090	0.034
041238	0.492	0.120	0.060	041456	1.234	0.116	0.048
041240	1.031	0.134	0.048	041458	1.087	0.076	0.061
041242	0.692	0.136	0.050	041500	1.181	0.132	0.068
041245	0.951	0.089	0.052	041503	1.175	0.119	0.062
041247	0.628	0.112	0.057	041505	0.571	0.151	0.072
041249	0.838	0.111	0.079	041507	1.026	0.175	0.081
041252	0.434	0.087	0.055	041510	1.230	0.129	0.037
041254	1.058	0.137	0.084	041512	0.852	0.182	0.075
041256	0.720	0.131	0.083	041514	0.973	0.101	0.084
041258	0.894	0.110	0.035	041516	1.103	0.143	0.075
041301	0.871	0.136	0.051	041519	1.074	0.154	0.077
041303	0.773	0.157	0.056	041521	1.330	0.193	0.094
041305	0.671	0.129	0.067	041523	1.225	0.222	0.081
041308	0.691	0.163	0.056	041526	1.761	0.203	0.070
041310	0.763	0.152	0.044	041528	1.584	0.219	0.106
041312	0.683	0.117	0.050	041530	1.418	0.259	0.136
041315	0.858	0.083	0.047	041533	1.964	0.227	0.105
041317	0.847	0.082	0.046	041535	1.995	0.280	0.104
041319	0.658	0.107	0.058	041537	1.700	0.304	0.097
041321	1.033	0.056	0.054	041539	1.776	0.306	0.109
041324	0.588	0.088	0.048	041542	1.874	0.336	0.137
041326	0.443	0.090	0.049	041544	2.031	0.354	0.144
041328	0.721	0.112	0.042	041546	1.804	0.224	0.110
041331	-0.026	0.063	0.047	041549	1.796	0.249	0.117
041333	1.050	0.050	0.043	041551	1.941	0.260	0.099
041335	0.638	0.032	0.033	041553	1.231	0.244	0.096
041338	0.462	0.056	0.046	041556	1.315	0.152	0.100
041340	0.425	0.081	0.052	041558	0.802	0.219	0.101
041342	0.536	0.090	0.047	041600	1.157	0.145	0.088
041344	0.631	0.072	0.021	041602	1.128	0.124	0.076
041347	0.570	0.114	0.025	041605	1.129	0.167	0.091
041349	0.706	0.070	0.063	041607	1.161	0.220	0.046
041351	0.224	0.042	0.026	041609	1.341	0.178	0.061
041354	0.424	0.041	0.031	041612	1.361	0.141	0.063
041356	0.265	0.054	0.058	041614	1.193	0.117	0.052
041358	0.484	0.002	0.046	041616	0.465	0.163	0.056
041401	0.396	0.098	0.022	041619	1.066	0.151	0.066
041403	0.163	0.108	0.034	041621	1.227	0.118	0.057
041405	0.348	0.095	0.043	041623	0.966	0.078	0.056
041407	0.233	0.060	0.032	041625	0.813	0.117	0.064
041410	0.293	0.089	0.027	041628	0.958	0.120	0.055
041412	0.858	0.028	0.026	041630	0.971	0.162	0.031
041414	0.334	0.073	0.026	041632	1.226	0.152	0.065
041417	0.531	0.049	0.045	041635	1.063	0.105	0.072
041419	0.646	0.085	0.054	041637	0.927	0.175	0.063
041421	0.302	0.038	0.021	041639	1.092	0.175	0.052
041424	0.459	0.080	0.034	041642	0.853	0.115	0.054
041426	0.599	0.093	0.034	041644	0.740	0.165	0.070
041428	0.825	0.072	0.044	041646	0.967	0.106	0.074
041430	0.424	0.058	0.030	041648	1.177	0.089	0.088
041433	0.713	0.108	0.040	041651	0.722	0.096	0.068
041435	0.290	0.031	0.034	041653	0.957	0.134	0.043
041437	0.352	0.068	0.018	041655	0.296	0.121	0.090
041440	0.599	0.059	0.018	041658	0.904	0.130	0.053
041442	0.814	0.057	0.007	041700	0.869	0.141	0.060
041444	0.587	0.078	0.027	041702	0.843	0.107	0.058
041447	0.692	0.049	0.022	041705	0.650	0.113	0.057

APPENDIX 2 - CONTINUED

EV LAC OCT 9, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
041707	0.954	0.060	0.075	041925	0.738	0.078	0.013
041709	1.109	0.154	0.068	041927	0.451	0.015	0.020
041711	0.954	0.114	0.062	041929	-0.058	0.042	0.034
041714	1.285	0.101	0.042	041932	0.510	0.030	0.005
041716	0.716	0.041	0.035	041934	0.252	0.046	0.020
041718	0.969	0.090	0.073	041936	0.239	0.049	0.003
041721	0.540	0.041	0.074	041939	0.300	-0.007	0.008
041723	0.914	0.054	0.056	041941	0.671	0.130	0.010
041725	0.385	0.091	0.059	041943	0.406	0.027	-0.003
041728	0.738	0.064	0.044	041946	0.593	0.024	-0.016
041730	0.627	0.099	0.034	041948	0.607	0.034	0.023
041732	0.998	0.070	0.052	041950	0.367	0.021	0.032
041734	0.588	0.067	0.031	041952	0.447	0.080	0.014
041737	1.018	0.085	0.025	041955	0.307	0.010	0.014
041739	0.503	0.068	0.034	041957	0.640	0.060	0.009
041741	0.382	0.089	0.036	041959	0.533	0.027	-0.001
041744	0.490	0.057	0.029	042002	0.584	0.087	0.015
041746	0.337	0.056	0.032	042004	0.934	0.025	-0.014
041748	0.673	0.068	0.016	042006	0.805	0.030	0.011
041751	0.604	0.090	0.022	042009	0.413	0.032	0.007
041753	0.919	0.150	0.039	042011	0.136	-0.005	-0.030
041755	1.092	0.073	0.040	042013	0.521	-0.006	-0.041
041757	1.003	0.103	0.027	042015	0.373	0.019	-0.045
041800	0.850	0.079	-0.007	042018	0.424	-0.045	-0.052
041802	1.003	0.066	0.003	042020	0.368	0.010	-0.038
041804	0.730	0.078	0.022	042022	0.693	0.001	-0.005
041807	0.373	0.055	0.015	042025	0.345	0.007	-0.011
041809	0.318	0.068	0.063	042027	0.187	-0.013	-0.021
041811	1.149	0.096	0.017	042029	0.640	0.020	-0.001
041814	0.519	0.146	0.047	042032	0.619	0.012	-0.007
041816	0.455	0.041	0.042	042034	0.625	0.005	0.017
041818	0.483	0.097	0.034	042036	0.737	0.036	0.009
041820	0.565	0.053	0.034	042038	0.671	0.059	0.018
041823	0.869	0.119	0.037	042041	0.291	0.032	0.028
041825	0.977	0.036	0.026	042043	0.696	0.009	0.003
041827	0.559	0.092	0.032	042045	0.460	0.006	-0.012
041830	0.586	0.138	0.043	042048	0.587	-0.014	-0.009
041832	0.414	0.046	0.024	042050	0.580	0.062	0.030
041834	1.032	0.102	0.031	042052	0.492	-0.033	0.026
041837	0.431	0.052	0.030	042055	0.437	0.071	0.003
041839	0.672	0.032	0.052	042057	0.501	0.041	-0.006
041841	0.660	0.013	0.039	042059	0.366	0.007	0.012
041843	1.037	0.091	0.037	042101	0.139	0.063	0.005
041846	0.663	0.076	0.013	042104	0.442	0.026	-0.019
041848	0.775	0.056	0.015	042106	0.610	-0.034	-0.010
041850	0.382	0.091	0.032	042108	0.076	0.014	0.031
041853	0.468	0.084	0.031	042111	0.400	0.027	-0.005
041855	0.818	0.098	0.020	042113	0.303	0.017	0.028
041857	0.751	0.053	0.029	042115	0.052	0.001	-0.008
041900	0.530	0.079	0.014	042118	0.257	-0.029	0.008
041902	0.376	0.019	0.035	042120	0.531	0.021	-0.010
041904	0.375	0.068	0.045	042122	0.278	0.036	0.010
041906	0.282	0.078	0.019	042124	0.462	-0.012	-0.015
041909	0.568	0.075	0.044	042127	0.377	-0.009	-0.001
041911	0.650	0.064	0.004	042129	0.160	0.015	-0.008
041913	0.522	0.051	0.016	042131	0.235	0.047	-0.014
041916	0.720	0.087	0.010	042134	0.178	-0.014	-0.014
041918	0.726	0.059	0.012	042136	0.764	0.010	-0.017
041920	0.252	0.042	0.031	042138	0.132	0.024	-0.022
041923	0.567	0.048	-0.005	042141	0.358	0.015	0.013

APPENDIX 2 - CONTINUED

EV LAC OCT 9, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
042143	0.359	0.041	0.010	042401	0.044	0.022	0.001
042145	0.598	0.039	0.009	042403	0.352	-0.000	0.014
042147	0.210	-0.021	0.024	042405	0.182	0.059	0.010
042150	0.713	0.004	0.005	042408	0.407	-0.016	0.030
042152	0.449	0.013	0.008	042410	0.512	0.002	0.013
042154	0.433	0.029	-0.007	042412	-0.183	0.016	0.006
042157	0.228	0.043	0.016	042415	0.683	0.054	0.062
042159	0.428	0.046	0.008	042417	0.129	-0.029	0.009
042201	0.370	-0.013	0.020	042419	0.090	0.001	0.028
042204	0.223	0.026	0.021	042422	0.365	0.014	0.027
042206	0.257	-0.005	0.015	042424	0.155	0.015	-0.000
042208	0.265	0.038	0.018	042426	0.689	0.013	0.008
042210	0.491	0.041	0.022	042428	0.040	0.039	0.043
042213	0.280	0.034	0.025	042431	-0.119	0.008	0.003
042215	0.236	0.049	0.029	042433	0.480	0.020	0.036
042217	0.210	-0.003	0.008	042435	0.452	0.036	0.029
042220	0.000	0.038	0.019	042438	0.134	0.021	0.028
042222	0.304	0.036	0.006	042440	0.756	0.049	0.019
042224	0.211	0.047	0.029	042442	0.442	-0.020	0.006
042227	0.152	0.010	0.049	042445	-0.095	0.034	0.006
042229	0.511	0.053	0.033	042447	0.337	0.047	0.016
042231	0.090	0.062	0.018	042449	0.378	-0.010	0.022
042233	0.409	0.089	0.018	042451	-0.008	0.079	0.034
042236	0.728	0.074	0.039	042454	0.233	0.033	0.025
042238	0.427	0.032	0.021	042456	-0.006	-0.037	0.023
042240	0.456	0.048	0.012	042458	0.006	0.004	0.016
042243	0.380	-0.014	0.020	042501	-0.172	0.028	0.001
042245	0.288	0.046	0.032	042503	0.456	-0.014	0.010
042247	0.593	0.055	0.016	042505	0.499	0.018	0.021
042250	0.348	0.095	0.025	042508	-0.005	0.022	0.018
042252	0.568	0.048	0.014	042510	0.510	0.047	0.041
042254	0.568	0.020	0.001	042512	0.381	-0.050	0.013
042256	0.228	0.030	-0.004	042514	0.287	0.006	0.017
042259	0.241	-0.016	0.012	042517	0.017	-0.020	0.019
042301	0.110	0.034	0.016	042519	0.580	-0.038	0.006
042303	0.579	0.004	0.032	042521	0.451	0.074	0.030
042306	0.365	0.104	0.026	042524	0.404	-0.021	0.001
042308	0.304	0.003	0.021	042526	0.267	0.025	-0.004
042310	0.367	0.030	0.042	042528	0.637	0.015	0.016
042313	0.165	0.045	0.027	042531	0.186	-0.010	0.003
042315	0.147	0.090	0.022	042533	-0.002	0.056	0.012
042317	0.316	0.032	0.039	042535	0.165	0.019	0.029
042319	0.120	0.053	0.022	042537	0.425	0.012	0.007
042322	0.286	0.036	0.009	042540	0.568	0.007	0.029
042324	0.343	-0.020	0.018	042544	0.405	-0.006	0.004
042326	0.404	0.015	0.019	042547	0.040	0.064	0.005
042329	0.508	0.014	0.041	042549	0.104	0.028	0.023
042331	0.569	0.010	-0.002	042551	0.366	-0.011	0.040
042333	0.037	0.060	0.019	042554	0.123	0.004	0.050
042336	0.388	0.060	0.020	042556	0.261	-0.014	0.017
042338	0.393	-0.020	0.023	042558	0.310	-0.004	0.012
042340	0.255	0.008	0.021	042600	0.267	0.020	0.006
042342	0.544	0.054	0.043	052949	0.025	0.033	-0.004
042345	0.302	-0.008	0.015	052952	0.223	0.037	0.049
042347	-0.028	0.028	0.027	052954	0.511	0.068	0.036
042349	0.812	0.068	0.016	052956	0.522	0.102	0.045
042352	0.123	0.041	0.029	052959	1.320	0.138	0.068
042354	0.410	-0.017	0.028	053001	1.768	0.252	0.106
042356	0.378	0.041	0.016	053003	2.107	0.324	0.129
042359	0.087	-0.036	0.012	053005	2.059	0.379	0.109

APPENDIX 2 - CONTINUED

EV LAC OCT 9, 1973 (CONT.)

TIME	U	B	R	TIME	U	B	R
053008	2.713	0.376	0.151	053205	0.474	0.141	0.041
053010	2.959	0.458	0.141	053207	0.554	0.064	0.039
053012	2.800	0.443	0.180	053210	0.621	0.096	0.059
053015	3.175	0.498	0.181	053212	0.159	0.104	0.053
053017	3.224	0.495	0.198	053214	0.554	0.068	0.052
053019	3.299	0.490	0.192	053217	0.789	0.085	0.070
053022	2.895	0.419	0.166	053219	0.557	0.085	0.039
053024	2.466	0.376	0.150	053221	0.661	0.038	0.047
053026	2.260	0.313	0.144	053223	0.947	0.063	0.027
053028	2.217	0.337	0.135	053226	0.491	0.083	0.048
053031	1.765	0.333	0.132	053228	0.301	0.059	0.035
053033	2.465	0.331	0.172	053230	0.562	0.067	0.043
053035	2.338	0.349	0.134	053233	-0.090	0.016	0.033
053038	2.371	0.321	0.138	053235	0.593	0.002	0.049
053040	1.966	0.274	0.124	053237	1.013	0.037	0.014
053042	1.936	0.295	0.124	053240	0.257	0.092	0.029
053045	1.289	0.194	0.104	053242	0.271	0.073	0.032
053047	2.755	0.295	0.099	053244	0.353	0.092	0.030
053049	1.397	0.206	0.110	053246	0.360	0.083	0.045
053051	1.366	0.216	0.123	053249	0.496	0.071	0.046
053054	1.283	0.204	0.103	053251	0.812	0.080	0.028
053056	1.219	0.223	0.112	053253	0.577	0.064	0.039
053058	1.040	0.158	0.089	053256	0.603	0.081	0.043
053101	1.140	0.152	0.081	053258	0.257	0.056	0.018
053103	1.286	0.184	0.047	053300	0.413	0.061	0.018
053105	1.357	0.163	0.065	053303	0.256	0.041	0.051
053108	1.227	0.125	0.090	053305	0.143	0.065	0.033
053110	0.747	0.133	0.063	053307	0.378	0.060	0.033
053112	1.352	0.132	0.075	053309	0.095	0.016	0.063
053114	1.110	0.133	0.077	053312	0.306	0.038	0.049
053117	0.914	0.059	0.054	053314	0.623	0.053	0.028
053119	0.750	0.115	0.057	053316	0.448	0.045	0.010
053121	0.385	0.103	0.057	053319	0.254	0.093	0.029
053124	1.280	0.126	0.055	053321	0.599	0.038	0.008
053126	0.740	0.084	0.042	053323	-0.063	0.028	0.033
053128	0.946	0.099	0.042	053326	0.495	0.026	0.028
053131	0.849	0.145	0.045	053328	0.330	0.038	0.019
053133	1.525	0.088	0.049	053330	0.432	0.008	-0.012
053135	0.796	0.099	0.057	053332	0.547	0.059	0.016
053137	0.630	0.188	0.067	053335	0.371	0.105	0.056
053140	0.664	0.158	0.073	053337	-0.054	0.027	0.014
053142	0.189	0.127	0.053	053339	0.586	0.091	0.068
053144	1.070	0.106	0.053	053342	0.257	0.050	0.002
053147	0.782	0.097	0.049	053344	0.291	-0.002	-0.008
053149	0.467	0.125	0.044	053346	0.469	0.049	0.001
053151	1.278	0.085	0.055	053349	0.168	0.002	0.021
053154	0.616	0.107	0.030	053351	0.072	0.019	0.023
053156	1.174	0.066	0.039	053353	-0.156	0.006	0.007
053158	0.419	0.122	0.035	053355	0.470	0.005	0.030
053200	0.691	0.079	0.053	053358	0.190	0.068	0.018
053203	0.589	0.089	0.024	053400	0.433	0.027	0.001

APPENDIX 2 - CONTINUED

AD LEC FEB 21, 1974

TIME	U	B	R	TIME	U	B	R
050504	-0.021	-0.034	0.002	050703	0.072	-0.015	0.008
050507	-0.032	-0.013	0.003	050706	0.094	0.013	0.022
050510	-0.058	-0.003	0.019	050709	0.526	0.103	0.041
050514	-0.137	0.001	0.008	050712	2.125	0.295	0.071
050517	-0.091	0.002	0.020	050716	1.590	0.349	0.077
050520	0.010	-0.007	-0.006	050719	1.430	0.257	0.063
050524	-0.175	-0.021	-0.016	050722	1.014	0.188	0.045
050527	-0.086	-0.010	-0.009	050726	0.826	0.161	0.050
050530	-0.041	-0.014	0.002	050729	0.813	0.126	0.064
050533	0.025	-0.015	0.000	050732	0.907	0.101	0.040
050537	-0.179	-0.017	-0.010	050736	0.941	0.106	0.034
050540	0.267	-0.039	-0.015	050739	0.495	0.075	0.023
050543	-0.087	-0.024	-0.019	050742	0.473	0.095	0.036
050547	-0.035	-0.037	-0.014	050745	0.436	0.085	0.028
050550	-0.118	-0.048	-0.016	050749	0.450	0.080	0.034
050553	-0.011	-0.042	-0.022	050752	0.207	0.078	0.048
050557	-0.030	-0.039	-0.001	050755	0.167	0.060	0.032
050600	-0.126	-0.030	-0.017	050759	0.256	0.074	0.029
050603	0.001	-0.051	-0.035	050802	0.248	0.051	0.034
050606	-0.004	-0.031	-0.019	050805	0.340	0.048	0.030
050610	0.016	-0.036	-0.024	050809	0.290	0.052	0.023
050613	-0.080	-0.052	-0.010	050812	0.353	0.053	0.027
050616	-0.180	-0.058	-0.014	050815	0.382	0.043	0.038
050620	-0.072	-0.028	0.005	050818	0.363	0.069	0.033
050623	-0.026	-0.012	0.001	050822	0.046	0.036	0.031
050626	-0.105	-0.024	-0.002	050825	0.347	0.030	0.023
050630	0.001	-0.020	0.015	050828	0.365	0.032	0.020
050633	-0.101	-0.021	0.008	050832	0.249	0.026	0.028
050636	-0.138	-0.033	0.011	050835	0.141	0.037	0.029
050639	0.048	-0.030	-0.001	050838	0.247	0.058	0.013
050643	-0.035	-0.011	-0.005	050842	0.381	0.015	0.026
050646	0.081	-0.024	-0.003	050845	0.180	0.016	0.016
050649	-0.049	-0.014	0.008	050848	0.163	0.017	0.018
050653	-0.105	-0.018	0.014	050851	0.062	0.027	0.020
050656	0.275	-0.020	0.016	050855	0.096	0.010	0.014
050659	-0.032	-0.013	0.016	050858	0.161	-0.015	0.001

APPENDIX 2 - CONTINUED

AD LEO FEB 26, 1974

TIME	U	B	R	TIME	U	B	R
044855	2.116	0.226	0.042	045116	1.328	0.224	0.030
044858	2.490	0.407	0.063	045118	1.306	0.228	0.032
044900	3.692	0.598	0.113	045123	1.787	0.238	0.068
044902	5.729	0.896	0.163	045125	1.571	0.267	0.049
044905	7.001	1.205	0.211	045127	1.419	0.264	0.055
044909	8.654	1.781	0.274	045130	1.796	0.249	0.065
044909	8.654	1.781	0.274	045132	1.647	0.304	0.062
044912	7.988	1.781	0.196	045134	2.126	0.304	0.078
044914	8.386	1.781	0.219	045141	2.102	0.305	0.052
044916	7.035	1.781	0.218	045143	1.667	0.328	0.078
044918	7.331	1.780	0.230	045146	2.360	0.337	0.060
044921	6.454	1.780	0.192	045148	2.294	0.331	0.073
044923	6.191	1.780	0.199	045150	2.121	0.360	0.073
044925	6.046	1.780	0.203	045153	1.854	0.367	0.083
044928	5.899	1.780	0.201	045155	2.030	0.396	0.071
044932	5.166	1.112	0.163	045157	2.258	0.347	0.040
044935	4.864	0.899	0.137	045159	2.726	0.354	0.067
044937	4.470	0.752	0.100	045202	2.883	0.416	0.080
044939	4.498	0.717	0.101	045204	2.578	0.483	0.084
044941	4.030	0.660	0.087	045206	3.246	0.498	0.068
044944	3.616	0.600	0.097	045209	3.236	0.553	0.082
044946	4.188	0.631	0.095	045211	3.261	0.531	0.059
044948	3.657	0.633	0.128	045213	3.349	0.616	0.105
044951	3.957	0.584	0.121	045216	3.883	0.700	0.141
044953	3.406	0.604	0.100	045218	3.993	0.751	0.162
044955	3.570	0.570	0.117	045220	4.327	0.739	0.110
044958	3.726	0.564	0.127	045222	4.379	0.813	0.122
045000	3.298	0.551	0.098	045225	4.842	0.889	0.155
045002	3.107	0.522	0.112	045227	4.611	0.887	0.149
045004	2.797	0.518	0.106	045229	5.809	0.972	0.176
045007	2.908	0.526	0.115	045232	6.245	1.030	0.188
045009	3.505	0.539	0.110	045234	6.417	1.042	0.190
045011	3.092	0.482	0.081	045243	7.415	1.439	0.240
045014	3.139	0.470	0.085	045245	7.382	1.394	0.251
045016	2.493	0.453	0.071	045248	8.420	1.481	0.276
045018	2.826	0.451	0.095	045250	8.412	1.509	0.265
045021	2.789	0.417	0.071	045252	8.566	1.555	0.291
045023	2.497	0.359	0.067	045255	8.803	1.589	0.296
045025	2.417	0.346	0.066	045257	9.507	1.664	0.308
045027	2.495	0.361	0.084	045259	8.537	1.649	0.285
045030	2.342	0.366	0.081	045302	9.215	1.670	0.301
045032	2.036	0.376	0.064	045304	8.991	1.686	0.311
045034	2.034	0.343	0.082	045306	9.257	1.669	0.303
045037	2.093	0.337	0.071	045308	8.186	1.539	0.258
045039	2.143	0.320	0.080	045311	6.702	1.321	0.225
045041	1.784	0.309	0.069	045313	6.847	1.221	0.221
045044	2.092	0.265	0.072	045315	6.211	1.138	0.196
045046	2.189	0.264	0.069	045318	5.704	1.044	0.214
045048	1.701	0.281	0.063	045320	5.510	0.974	0.200
045050	2.028	0.271	0.066	045322	5.027	0.912	0.193
045053	1.725	0.275	0.070	045325	4.542	0.854	0.169
045055	1.423	0.268	0.065	045327	4.847	0.747	0.139
045057	1.759	0.245	0.041	045329	4.255	0.668	0.137
045100	1.767	0.233	0.053	045331	3.354	0.601	0.113
045102	1.843	0.217	0.045	045334	3.099	0.526	0.086
045104	1.743	0.262	0.062	045336	2.952	0.528	0.099
045107	1.433	0.218	0.029	045338	2.980	0.471	0.078
045109	1.379	0.165	0.009	045341	2.805	0.447	0.092
045111	1.467	0.158	0.004	045343	3.059	0.421	0.091
045113	1.293	0.179	0.035	045345	3.058	0.386	0.067

APPENDIX 2 - CONTINUED

AD LEC FEB 26, 1974 (CONT.)

TIME	L	B	R	TIME	L	B	R
045348	2.875	0.392	0.090	045610	3.104	0.455	0.087
045350	2.822	0.349	0.059	045612	3.293	0.503	0.102
045352	2.375	0.320	0.059	045615	3.226	0.503	0.082
045354	2.413	0.344	0.079	045617	3.278	0.526	0.103
045357	2.541	0.314	0.050	045619	3.212	0.489	0.105
045359	2.434	0.310	0.041	045622	3.002	0.521	0.110
045401	2.326	0.306	0.037	045624	3.463	0.520	0.112
045404	2.115	0.301	0.025	045626	3.201	0.482	0.072
045406	2.400	0.280	0.034	045629	3.067	0.468	0.099
045408	2.372	0.273	0.056	045631	2.814	0.419	0.073
045411	2.367	0.350	0.086	045633	2.704	0.441	0.086
045413	2.710	0.382	0.072	045635	2.974	0.478	0.101
045415	2.371	0.383	0.066	045638	3.110	0.476	0.100
045417	2.807	0.387	0.088	045640	2.771	0.490	0.063
045420	2.609	0.353	0.075	045642	2.926	0.483	0.083
045422	2.454	0.392	0.094	045645	2.818	0.453	0.077
045424	2.876	0.379	0.100	045647	2.674	0.446	0.095
045427	2.796	0.395	0.100	045649	2.534	0.403	0.051
045429	2.767	0.392	0.071	045652	2.558	0.412	0.068
045431	2.506	0.405	0.098	045654	2.528	0.435	0.066
045434	2.303	0.421	0.098	045656	2.717	0.426	0.072
045436	3.020	0.395	0.094	045658	2.832	0.415	0.084
045438	2.783	0.390	0.077	045701	2.668	0.428	0.098
045440	2.770	0.390	0.056	045703	2.854	0.437	0.101
045443	2.871	0.392	0.052	045705	2.621	0.444	0.113
045445	3.156	0.422	0.082	045708	2.710	0.438	0.094
045447	2.668	0.394	0.045	045710	2.674	0.396	0.090
045450	2.707	0.395	0.051	045712	2.408	0.359	0.078
045452	2.926	0.375	0.054	045715	2.539	0.344	0.054
045454	3.057	0.428	0.093	045717	2.549	0.376	0.070
045457	3.441	0.463	0.103	045719	3.042	0.390	0.099
045459	3.165	0.502	0.126	045721	2.256	0.367	0.087
045501	3.368	0.535	0.106	045724	2.426	0.374	0.096
045503	3.825	0.516	0.099	045726	2.986	0.371	0.085
045506	3.052	0.544	0.113	045728	2.464	0.373	0.089
045508	2.962	0.527	0.112	045731	2.224	0.372	0.059
045510	3.363	0.527	0.107	045733	2.214	0.366	0.064
045513	3.538	0.532	0.122	045735	2.166	0.349	0.077
045515	3.113	0.526	0.110	045738	2.196	0.371	0.091
045517	3.323	0.559	0.122	045740	2.704	0.386	0.095
045520	3.343	0.527	0.096	045742	2.485	0.377	0.096
045522	2.932	0.448	0.045	045744	2.640	0.356	0.084
045525	2.991	0.428	0.079	045747	2.282	0.357	0.091
045531	3.003	0.390	0.038	045749	2.238	0.358	0.080
045533	2.939	0.395	0.029	045751	2.290	0.364	0.078
045536	2.974	0.387	0.033	045754	2.688	0.346	0.089
045538	2.574	0.358	0.021	045756	2.264	0.377	0.088
045540	2.637	0.367	0.038	045758	2.517	0.396	0.110
045543	2.701	0.425	0.041	045801	2.630	0.381	0.091
045545	3.073	0.459	0.081	045803	2.384	0.376	0.092
045547	3.271	0.464	0.083	045805	2.328	0.385	0.100
045549	3.407	0.458	0.074	045807	2.358	0.363	0.080
045552	2.929	0.411	0.043	045810	2.327	0.328	0.069
045554	2.596	0.405	0.034	045812	2.001	0.339	0.064
045556	2.984	0.441	0.042	045814	2.167	0.356	0.063
045559	3.267	0.453	0.068	045817	2.271	0.343	0.058
045601	3.304	0.446	0.070	045819	2.736	0.317	0.067
045603	3.102	0.440	0.070	045821	2.343	0.326	0.075
045606	2.956	0.456	0.063	045824	2.310	0.324	0.059
045608	3.099	0.476	0.082	045826	2.365	0.340	0.079

APPENDIX 2 - CONTINUED

AD LEO FEB 26, 1974 (CONT.)

TIME	U	B	R	TIME	U	B	R
045828	2.375	0.364	0.065	050051	1.889	0.355	0.085
045830	2.724	0.357	0.080	050053	2.449	0.368	0.070
045833	2.403	0.378	0.086	050055	2.135	0.326	0.070
045835	2.405	0.354	0.080	050058	1.757	0.305	0.050
045837	2.187	0.372	0.087	050100	2.400	0.298	0.049
045840	2.255	0.337	0.060	050102	1.796	0.314	0.058
045842	2.275	0.334	0.052	050105	1.806	0.351	0.064
045844	2.113	0.350	0.059	050107	2.157	0.327	0.081
045847	2.210	0.341	0.058	050109	2.430	0.343	0.086
045849	2.389	0.341	0.066	050111	1.848	0.357	0.090
045851	2.659	0.354	0.064	050114	2.539	0.365	0.091
045853	2.367	0.325	0.072	050116	2.193	0.364	0.078
045856	2.107	0.349	0.052	050118	2.597	0.356	0.078
045858	2.494	0.342	0.084	050121	2.367	0.361	0.098
045900	2.297	0.329	0.031	050123	2.256	0.340	0.076
045903	2.356	0.314	0.042	050125	2.514	0.339	0.088
045905	2.041	0.309	0.053	050128	2.283	0.364	0.080
045907	2.240	0.331	0.047	050130	1.856	0.343	0.092
045910	2.280	0.297	0.033	050132	2.195	0.359	0.077
045912	2.421	0.313	0.063	050134	2.274	0.349	0.086
045914	2.249	0.315	0.062	050137	1.983	0.372	0.063
045916	2.310	0.329	0.069	050139	2.144	0.336	0.072
045919	2.542	0.353	0.087	050141	2.350	0.365	0.074
045921	2.306	0.325	0.073	050144	2.413	0.303	0.055
045923	2.209	0.350	0.074	050146	2.241	0.311	0.055
045926	2.358	0.364	0.099	050148	1.863	0.343	0.068
045928	2.120	0.360	0.095	050151	1.977	0.361	0.074
045930	2.081	0.352	0.084	050153	2.080	0.355	0.078
045933	2.524	0.347	0.075	050155	2.567	0.370	0.074
045935	2.789	0.345	0.061	050157	2.571	0.353	0.076
045937	1.884	0.328	0.056	050200	2.519	0.364	0.069
045939	2.210	0.355	0.033	050202	2.145	0.361	0.082
045942	2.256	0.295	0.043	050204	2.057	0.370	0.099
045944	2.285	0.319	0.043	050207	2.318	0.348	0.081
045946	2.392	0.340	0.065	050209	2.028	0.341	0.076
045949	2.490	0.361	0.064	050211	2.052	0.355	0.076
045951	2.387	0.361	0.069	050214	2.058	0.352	0.075
045953	2.505	0.360	0.070	050216	1.907	0.344	0.067
045956	2.590	0.354	0.059	050218	2.071	0.328	0.075
045958	2.326	0.349	0.067	050220	2.201	0.316	0.065
050000	2.309	0.351	0.091	050223	2.585	0.336	0.079
050002	2.333	0.361	0.084	050225	2.566	0.355	0.081
050005	2.273	0.358	0.077	050227	2.142	0.343	0.078
050007	2.414	0.353	0.095	050230	2.313	0.372	0.077
050009	2.461	0.343	0.078	050232	2.162	0.337	0.076
050016	1.958	0.353	0.089	050234	2.086	0.344	0.055
050019	2.104	0.330	0.095	050237	2.298	0.298	0.066
050021	2.149	0.356	0.090	050239	2.083	0.339	0.084
050023	2.291	0.354	0.074	050241	2.033	0.316	0.071
050025	2.548	0.363	0.084	050243	2.404	0.328	0.075
050028	2.444	0.376	0.088	050246	2.269	0.347	0.068
050030	2.328	0.366	0.086	050248	2.132	0.363	0.077
050032	1.939	0.373	0.071	050250	1.573	0.334	0.086
050035	2.300	0.351	0.086	050253	2.071	0.342	0.086
050037	2.041	0.342	0.046	050255	1.940	0.337	0.096
050039	2.131	0.306	0.048	050257	1.680	0.354	0.086
050042	2.020	0.264	0.012	050327	2.030	0.307	0.092
050044	2.111	0.216	0.003	050329	1.780	0.313	0.085
050046	2.153	0.302	0.054	050332	1.767	0.327	0.101
050048	2.122	0.357	0.084	050334	2.173	0.334	0.098

APPENDIX 2 - CONTINUED

AD LEO FEB 26, 1974 (CONT.)

TIME	U	B	R	TIME	U	B	R
050336	2.253	0.343	0.084	050554	2.124	0.319	0.089
050338	2.377	0.347	0.100	050556	1.775	0.352	0.098
050341	1.983	0.338	0.102	050559	1.917	0.324	0.083
050343	2.282	0.343	0.100	050601	1.819	0.326	0.097
050345	1.768	0.350	0.097	050606	1.729	0.310	0.083
050346	1.667	0.354	0.086	050608	1.646	0.326	0.086
050350	2.252	0.319	0.095	050610	2.421	0.340	0.101
050352	1.981	0.342	0.085	050613	1.923	0.343	0.094
050355	2.160	0.315	0.089	050615	1.876	0.352	0.092
050357	1.962	0.342	0.094	050617	2.150	0.344	0.091
050359	2.144	0.322	0.093	050619	1.858	0.347	0.097
050401	2.094	0.356	0.111	050622	1.750	0.316	0.087
050404	2.514	0.338	0.105	050624	2.078	0.324	0.100
050406	2.049	0.347	0.109	050626	1.681	0.319	0.086
050408	2.074	0.327	0.088	050629	2.088	0.328	0.096
050411	1.932	0.334	0.079	050631	2.019	0.303	0.089
050413	2.187	0.332	0.094	050633	1.965	0.237	0.033
050415	2.191	0.340	0.096	050636	1.869	0.257	0.048
050418	1.946	0.330	0.106	050638	1.582	0.247	0.058
050420	1.868	0.328	0.092	050640	1.493	0.270	0.077
050422	2.022	0.332	0.097	050642	1.486	0.268	0.057
050424	2.217	0.322	0.090	050645	1.730	0.249	0.056
050427	1.702	0.342	0.096	050647	2.220	0.253	0.056
050429	2.050	0.336	0.083	050649	1.938	0.254	0.045
050431	2.434	0.341	0.108	050652	1.771	0.275	0.068
050434	2.143	0.356	0.098	050654	1.772	0.228	0.017
050436	2.022	0.364	0.093	050656	1.476	0.241	0.040
050438	2.001	0.334	0.092	050659	1.465	0.209	0.009
050441	2.283	0.335	0.099	050701	1.406	0.198	0.023
050443	1.906	0.324	0.094	050703	1.365	0.230	0.036
050445	2.118	0.329	0.092	050705	2.117	0.261	0.067
050447	2.128	0.347	0.086	050708	1.569	0.241	0.061
050450	2.110	0.320	0.083	050710	1.971	0.253	0.051
050452	1.775	0.331	0.086	050712	1.606	0.241	0.041
050454	1.743	0.311	0.086	050715	1.622	0.238	0.054
050457	1.828	0.324	0.075	050717	1.955	0.225	0.050
050459	2.414	0.325	0.074	050719	2.032	0.246	0.065
050501	1.749	0.305	0.087	050722	1.783	0.265	0.073
050504	1.711	0.323	0.084	050724	1.594	0.234	0.033
050506	1.908	0.303	0.100	050726	1.589	0.234	0.060
050508	1.620	0.332	0.094	050728	1.354	0.267	0.064
050510	1.851	0.338	0.098	050731	1.548	0.246	0.053
050513	2.102	0.349	0.100	050733	1.457	0.216	0.031
050515	1.672	0.321	0.083	050735	1.538	0.210	0.054
050517	1.882	0.346	0.100	050738	1.662	0.230	0.046
050520	2.060	0.350	0.092	050740	1.541	0.205	0.048
050522	2.041	0.341	0.094	050742	1.745	0.233	0.051
050524	1.818	0.348	0.087	050745	1.391	0.220	0.038
050527	2.216	0.355	0.113	050747	1.646	0.237	0.059
050529	1.933	0.370	0.105	050749	1.602	0.222	0.056
050531	2.010	0.337	0.096	050751	1.471	0.239	0.063
050533	2.003	0.332	0.090	050754	1.415	0.241	0.061
050536	2.120	0.347	0.095	050756	1.529	0.229	0.060
050538	1.851	0.358	0.094	050758	1.563	0.267	0.060
050540	1.875	0.335	0.091	050801	1.637	0.243	0.060
050543	1.910	0.322	0.096	050803	1.637	0.238	0.037
050545	1.719	0.322	0.088	050805	1.257	0.194	0.026
050547	1.942	0.327	0.079	050808	1.423	0.197	0.016
050550	1.966	0.336	0.078	050810	1.405	0.160	0.009
050552	1.934	0.322	0.092				

APPENDIX 2 - CONTINUED

AD LEO FEB 27, 1974

TIME	U	B	R	TIME	U	B	R
072130	0.279	-0.004	-0.004	072332	0.318	0.034	0.006
072132	0.189	0.034	-0.012	072334	0.310	0.028	0.004
072134	0.106	0.000	-0.015	072336	0.717	0.008	0.001
072137	0.330	0.012	-0.006	072339	0.199	0.010	0.010
072139	0.211	0.046	-0.001	072341	0.477	0.019	0.007
072141	0.285	-0.011	-0.004	072343	0.160	0.017	0.013
072144	0.335	0.013	-0.009	072345	0.381	0.014	-0.003
072146	0.407	0.042	-0.007	072348	0.244	0.012	0.009
072148	0.406	0.018	-0.006	072350	0.378	0.023	-0.007
072150	0.309	0.041	0.008	072352	0.271	0.021	-0.003
072153	0.278	0.056	0.010	072355	0.150	0.023	-0.005
072155	0.392	0.097	0.010	072357	0.054	0.011	0.001
072157	0.461	0.094	0.010	072359	0.112	0.032	0.000
072200	0.997	0.099	0.007	072402	0.205	0.022	0.001
072202	0.582	0.093	0.013	072404	0.125	0.032	-0.007
072204	0.834	0.119	0.004	072406	0.155	0.023	0.015
072207	0.814	0.105	-0.005	072408	0.160	0.024	0.004
072209	0.543	0.095	0.001	072411	0.362	0.016	-0.004
072211	0.452	0.087	0.005	072413	0.392	0.017	0.001
072213	0.891	0.123	0.017	072415	0.052	0.022	-0.006
072216	0.841	0.126	0.015	072418	0.265	0.010	0.008
072218	0.831	0.138	0.030	072420	0.509	0.036	-0.004
072220	0.781	0.103	0.016	072422	0.497	0.023	0.009
072223	0.470	0.099	0.002	072425	0.231	0.040	0.002
072225	0.316	0.098	0.018	072427	0.104	0.013	-0.003
072227	0.992	0.105	0.014	072429	0.411	0.031	-0.005
072230	0.673	0.101	0.007	072431	0.147	0.008	-0.006
072232	0.408	0.084	0.018	072434	0.131	-0.000	-0.002
072234	0.800	0.100	0.011	072436	0.149	-0.003	-0.000
072236	0.518	0.086	0.015	072438	0.356	0.011	0.003
072239	0.424	0.072	0.017	072441	0.261	0.042	-0.002
072241	0.931	0.052	0.014	072443	0.023	0.010	-0.004
072243	0.487	0.062	0.014	072445	-0.125	0.005	-0.006
072246	0.297	0.076	-0.006	072448	0.082	-0.001	0.002
072248	0.239	0.063	0.006	072450	0.251	0.011	-0.010
072250	0.617	0.043	-0.008	072452	0.165	0.015	0.004
072253	0.092	0.049	0.012	072454	0.587	0.024	0.003
072255	0.311	0.036	0.007	072457	0.028	0.038	-0.009
072257	0.475	0.022	0.013	072459	0.234	0.043	0.013
072259	0.334	0.032	0.008	072501	0.042	0.048	0.001
072302	0.264	0.026	0.002	072504	0.062	0.043	0.009
072304	0.309	0.023	0.007	072506	0.386	0.030	0.002
072306	0.272	0.030	-0.003	072508	0.191	0.021	0.017
072309	0.081	0.031	0.001	072511	-0.068	0.008	-0.010
072311	0.155	0.023	0.002	072513	0.039	0.000	-0.005
072313	0.285	0.050	-0.000	072515	0.159	0.003	-0.012
072316	0.115	0.034	0.011	072517	0.153	0.011	-0.006
072318	0.065	0.010	0.004	072520	-0.108	0.004	-0.004
072320	0.256	0.053	0.005	072522	0.155	-0.003	-0.002
072322	0.352	0.032	-0.007	072524	0.302	0.022	-0.007
072325	0.139	0.025	0.007	072527	0.397	0.010	0.009
072327	0.154	0.036	0.007	072529	0.034	0.008	0.011
072329	0.427	0.023	0.002	072531	0.176	0.024	-0.003

APPENDIX 2 - CONTINUED

AD LEO APR 25, 1974

TIME	U	B	R	TIME	U	B	R
045910	0.042	-0.014	-0.014	050042	0.438	0.011	-0.001
045912	0.148	-0.021	0.000	050044	0.497	0.041	0.009
045914	0.023	-0.023	-0.008	050046	0.547	0.065	0.001
045917	0.599	0.024	0.013	050049	0.595	0.055	0.011
045919	0.512	0.023	0.010	050051	0.302	0.016	-0.013
045921	0.879	0.067	0.015	050053	0.373	0.012	0.002
045924	1.123	0.156	0.032	050056	0.349	-0.011	-0.003
045926	1.398	0.236	0.040	050058	0.061	-0.013	0.009
045930	1.408	0.168	0.023	050100	0.005	0.010	0.009
045933	1.451	0.156	0.029	050102	-0.034	0.021	0.000
045935	1.397	0.134	0.020	050105	0.571	-0.002	0.001
045937	0.951	0.113	0.016	050109	0.406	0.026	-0.008
045940	0.922	0.148	0.016	050116	0.203	-0.019	-0.002
045942	0.754	0.153	0.021	050119	0.250	-0.007	-0.010
045944	0.690	0.130	0.023	050121	0.096	0.045	0.003
045947	0.759	0.052	0.017	050125	0.257	-0.001	-0.005
045949	0.627	0.064	0.013	050128	-0.012	0.010	-0.017
045951	0.535	0.067	0.015	050130	0.610	0.001	-0.010
045953	0.076	0.070	-0.006	050137	0.174	0.002	-0.006
045956	0.333	0.046	0.013	050139	-0.156	-0.017	-0.008
045958	0.298	0.091	-0.004	050142	0.023	-0.016	0.003
050000	0.292	0.043	0.016	050144	-0.002	-0.032	-0.006
050003	0.478	0.029	0.001	050146	0.074	-0.035	-0.001
050005	0.396	0.016	0.019	050148	-0.003	-0.031	-0.005
050007	0.262	0.081	0.009	050151	1.101	-0.055	-0.011
050010	0.501	0.051	0.009	050153	0.323	0.006	0.001
050012	0.254	0.035	0.020	050155	0.127	-0.035	-0.001
050014	0.417	0.031	0.009	050158	0.066	-0.036	-0.006
050016	0.533	0.065	-0.006	050200	0.035	0.002	-0.008
050023	0.291	0.039	0.012	050202	0.189	-0.036	-0.008
050026	0.244	0.018	0.005	050205	0.164	-0.024	-0.007
050028	0.190	0.052	-0.006	050207	0.199	0.027	-0.003
050030	0.312	0.015	0.005	050209	0.069	-0.045	-0.013
050033	0.168	0.021	0.011	050211	0.220	-0.030	-0.013
050035	0.476	0.026	0.002	050214	0.116	0.026	-0.002
050037	0.336	0.040	-0.013	050216	0.142	-0.028	-0.005
050039	0.033	0.034	0.017	050218	-0.204	0.011	-0.004

APPENDIX 2 - CONTINUED

EV LAC AUG 19, 1974

TIME	U	B	R	TIME	U	B	R
062521	0.107	-0.034	0.001	062719	0.178	0.021	-0.016
062524	0.021	0.044	-0.005	062721	0.030	0.020	0.003
062526	-0.036	-0.002	0.000	062723	0.197	0.043	-0.008
062528	-0.043	0.002	-0.002	062725	0.271	0.002	-0.020
062530	0.026	-0.021	0.002	062728	0.202	-0.012	-0.010
062533	0.209	0.059	0.005	062730	-0.020	-0.009	-0.011
062535	0.111	0.100	-0.004	062732	-0.039	-0.074	0.010
062537	0.118	0.051	-0.017	062735	0.289	-0.097	-0.019
062540	0.047	0.085	-0.003	062737	-0.011	0.033	-0.023
062542	0.137	0.014	-0.007	062739	0.062	0.024	0.003
062544	0.222	0.040	0.013	062742	0.174	0.032	0.009
062547	0.469	0.034	0.005	062744	-0.031	0.082	-0.005
062549	0.343	-0.024	-0.011	062746	0.045	0.016	0.001
062551	0.408	0.094	0.019	062748	-0.116	-0.096	-0.012
062553	0.531	0.087	0.010	062751	0.144	0.008	-0.004
062556	0.401	-0.009	0.021	062753	0.233	0.066	-0.001
062558	0.490	0.073	0.013	062755	0.068	-0.008	-0.021
062603	0.561	0.002	0.004	062800	0.233	0.053	0.016
062605	0.797	0.016	0.013	062802	0.110	-0.083	0.005
062607	0.508	0.099	0.013	062805	0.137	0.018	-0.015
062610	0.427	0.088	0.040	062807	0.038	0.004	-0.013
062612	0.546	0.090	0.003	062809	0.001	0.001	0.018
062614	0.643	0.085	0.016	062811	-0.017	0.124	-0.011
062619	0.798	0.028	0.015	062814	0.103	0.025	-0.009
062621	0.540	0.072	0.003	062816	0.169	0.044	0.004
062623	0.649	0.143	0.019	062818	0.010	0.065	-0.002
062626	0.500	0.035	0.025	062821	0.083	0.054	-0.009
062628	0.179	0.055	-0.011	062823	-0.139	-0.049	-0.019
062630	0.193	0.119	0.008	062825	0.172	0.081	-0.002
062633	0.274	0.010	-0.003	062830	0.227	0.084	-0.005
062635	0.237	0.073	0.009	062832	0.069	-0.013	-0.014
062637	0.370	0.086	0.008	062834	0.089	0.008	0.006
062639	0.102	-0.003	0.002	062837	0.156	0.073	-0.005
062642	0.247	0.001	0.014	062839	0.063	0.002	0.005
062644	0.220	0.072	-0.011	062841	0.055	-0.040	-0.014
062646	0.002	-0.017	-0.010	062844	0.091	-0.014	0.010
062649	0.053	0.060	0.017	062846	0.109	-0.008	-0.018
062651	0.088	0.007	0.007	062848	0.006	-0.018	-0.002
062653	0.167	0.049	-0.002	062851	0.144	-0.001	-0.016
062658	0.075	0.087	-0.004	062853	0.023	0.003	0.003
062700	0.099	0.003	-0.009	062855	0.084	0.067	-0.005
062702	0.111	0.005	0.005	062857	0.012	0.045	-0.014
062705	0.086	0.045	0.016	062900	0.223	0.039	-0.012
062707	0.226	0.066	-0.002	062902	-0.041	0.030	-0.013
062709	0.252	0.013	0.003	062904	0.217	-0.039	-0.032
062712	-0.040	0.014	0.021	062907	0.161	0.042	-0.003
062714	0.088	-0.025	-0.001	062909	-0.005	-0.021	-0.016
062716	0.164	0.094	-0.003				

APPENDIX 2 - CONTINUED

EV LAC SEP 21, 1974

TIME	U	B	R	TIME	U	B	R
045500	0.094	0.028	0.008	045732	0.492	0.010	0.011
045505	0.147	0.006	0.000	045736	0.462	0.065	0.006
045507	0.001	0.044	-0.009	045741	0.443	0.152	0.015
045509	0.047	0.065	0.000	045743	0.395	0.017	0.032
045511	0.162	0.006	0.005	045746	0.426	0.019	0.029
045514	0.141	0.016	-0.002	045748	0.354	0.072	0.024
045516	-0.009	-0.041	-0.003	045750	0.376	0.055	0.026
045518	0.085	0.008	0.015	045752	0.347	0.106	0.024
045521	0.086	0.068	0.005	045755	0.353	0.035	0.018
045523	0.140	-0.023	0.006	045757	0.332	0.118	0.018
045525	0.178	0.020	0.006	045759	0.405	0.087	0.022
045528	-0.043	-0.078	0.000	045804	0.435	0.024	0.006
045532	0.232	0.040	0.005	045806	0.387	-0.002	0.010
045534	0.200	0.032	0.009	045809	0.355	0.061	0.016
045539	0.610	0.148	0.017	045811	0.273	0.000	0.009
045541	0.645	0.140	0.019	045813	0.331	0.062	0.011
045544	0.826	0.215	0.032	045815	0.269	0.011	0.008
045546	1.328	0.188	0.043	045818	0.441	0.008	0.004
045548	2.326	0.597	0.077	045820	0.405	0.082	0.025
045551	3.085	0.544	0.102	045822	0.360	0.074	0.011
045553	2.577	0.435	0.077	045825	0.421	0.115	0.024
045555	1.759	0.240	0.060	045827	0.344	0.087	0.010
045557	1.313	0.213	0.027	045829	0.287	0.006	0.015
045600	0.880	0.068	0.034	045832	0.340	0.046	0.003
045602	0.584	0.063	0.021	045834	0.308	0.036	0.022
045604	0.410	0.066	0.026	045836	0.257	0.079	0.017
045607	0.786	0.080	0.030	045838	0.223	0.052	0.010
045609	0.755	0.058	0.023	045841	0.279	0.098	0.013
045611	0.634	0.114	0.029	045845	0.342	0.025	0.034
045614	0.573	0.081	0.019	045850	0.353	0.041	0.012
045616	0.484	0.103	0.020	045852	0.316	0.096	0.023
045618	0.722	0.081	0.016	045856	0.253	0.057	0.025
045620	0.573	0.078	0.013	045859	0.253	0.016	0.022
045625	0.629	0.093	0.033	045901	0.266	0.060	0.033
045627	0.426	0.066	0.022	045904	0.300	0.053	0.030
045630	0.535	0.008	0.037	045908	0.424	0.126	0.026
045632	0.549	0.047	0.014	045911	0.316	0.102	0.021
045634	0.497	0.065	0.018	045913	0.213	0.078	0.006
045637	0.636	0.079	0.012	045915	0.318	0.062	0.021
045641	0.476	0.079	0.012	045918	0.187	0.057	0.002
045643	0.377	0.098	0.030	045920	0.302	0.056	0.011
045646	0.503	-0.006	0.007	045922	0.138	0.018	0.013
045648	0.537	0.071	0.020	045924	0.384	0.046	0.022
045650	0.552	0.100	0.020	045927	0.305	0.081	0.015
045653	0.509	0.058	0.021	045929	0.298	0.050	0.023
045657	0.422	0.012	0.012	045931	0.136	-0.006	0.016
045700	0.550	0.077	0.013	045934	0.206	0.020	0.019
045702	0.530	0.064	0.025	045936	0.333	0.061	0.006
045704	0.618	0.002	0.015	045938	0.286	0.021	0.024
045706	0.583	0.077	0.021	045941	0.196	-0.005	0.022
045709	0.430	0.080	0.022	045943	0.152	0.100	0.012
045711	0.608	0.025	0.017	045947	0.390	0.060	0.012
045713	0.405	0.073	0.008	045950	0.261	0.041	0.015
045716	0.342	0.112	0.014	045952	0.223	0.042	0.006
045718	0.321	0.043	0.008	045954	0.234	-0.023	0.013
045720	0.171	0.053	0.009	045957	0.194	0.068	0.021
045723	0.231	0.030	0.008	045959	0.138	0.080	0.016
045725	0.287	-0.011	0.009	050001	0.082	0.172	0.017
045727	0.466	0.030	0.037	050004	0.100	0.070	0.017
045729	0.302	0.093	0.014	050006	0.191	0.026	0.012

APPENDIX 2 - CONTINUED

EV LAC SEP 21, 1974 (CONT.)

TIME	U	B	R	TIME	U	B	R
050008	0.167	0.039	0.023	050226	0.019	0.012	0.007
050010	0.223	-0.010	0.018	050228	0.034	-0.011	-0.000
050013	0.228	0.065	0.014	050231	0.088	-0.023	0.001
050015	0.227	-0.004	0.007	050233	0.113	0.067	0.005
050017	0.227	0.013	0.015	050235	0.131	-0.042	0.001
050020	0.269	-0.005	0.011	050238	0.169	-0.057	-0.001
050022	0.379	-0.046	0.007	050240	0.134	0.013	0.021
050024	0.306	0.033	0.019	050242	0.144	-0.047	-0.011
050027	0.313	0.049	0.029	050245	0.028	-0.023	0.002
050029	0.180	-0.013	0.015	050247	0.075	-0.026	-0.009
050031	0.199	0.014	0.021	050249	0.280	0.024	0.002
050033	0.272	-0.005	0.020	050251	0.305	-0.004	0.008
050036	0.069	0.040	0.014	050254	0.186	0.066	0.002
050038	0.123	0.056	0.015	050256	0.061	-0.011	0.002
050040	0.142	-0.014	0.021	050333	0.113	0.090	0.026
050043	0.187	0.040	0.019	050335	0.192	0.008	0.015
050045	0.251	-0.007	0.012	050337	0.137	0.052	0.018
050047	0.263	0.012	0.015	050339	0.066	0.065	0.008
050050	0.176	0.008	0.019	050342	0.093	0.003	0.003
050052	0.131	0.050	0.016	050344	0.100	0.022	0.010
050054	0.044	0.034	0.010	050349	-0.041	0.101	0.011
050056	0.117	0.098	0.024	050353	0.102	0.042	0.014
050059	0.167	0.060	0.017	050356	-0.017	0.010	0.013
050101	0.183	-0.005	0.008	050358	0.105	0.040	0.015
050103	0.229	-0.002	0.028	050400	0.089	0.008	0.005
050106	0.191	0.071	0.005	050402	-0.078	0.071	0.011
050108	0.164	0.024	0.025	050405	0.207	0.040	0.013
050110	0.185	0.031	0.015	050407	0.084	0.000	0.020
050113	0.246	-0.002	0.008	050409	0.028	0.096	0.014
050115	0.171	-0.014	0.018	050412	0.157	0.015	0.005
050117	0.219	0.046	0.025	050414	-0.007	0.015	0.013
050119	0.213	0.045	0.012	050416	0.068	0.093	0.007
050122	0.161	-0.054	0.023	050419	0.062	0.080	0.001
050124	-0.017	-0.009	0.008	050421	0.209	0.022	0.010
050126	0.155	0.065	0.031	050423	0.222	0.126	0.006
050129	0.086	0.033	-0.003	050425	0.307	0.061	0.019
050131	0.055	-0.033	-0.000	050428	0.111	-0.005	0.014
050133	0.115	-0.025	0.001	050430	0.085	0.074	0.020
050136	0.187	-0.041	0.013	050432	0.048	0.032	0.015
050138	0.183	-0.070	0.004	050439	0.077	-0.024	0.010
050140	0.153	0.047	0.023	050442	0.205	0.071	0.015
050142	0.160	0.005	0.002	050444	0.054	0.068	0.012
050145	0.133	0.062	0.012	050446	0.250	-0.034	-0.004
050147	0.259	0.012	0.026	050448	0.066	0.012	0.006
050149	0.286	-0.065	0.005	050451	0.010	-0.023	0.011
050152	0.141	0.012	0.013	050453	0.101	0.058	0.008
050154	0.212	0.010	0.011	050455	-0.066	0.034	0.010
050156	0.215	-0.048	-0.000	050458	0.045	-0.037	0.016
050159	0.248	0.004	0.013	050500	0.162	0.066	0.014
050201	0.297	-0.049	0.023	050502	0.098	0.012	0.005
050203	0.045	0.034	0.015	050509	-0.001	0.057	0.005
050205	0.043	0.016	0.007	050511	0.130	0.028	0.003
050208	0.157	0.021	0.006	050514	0.233	0.115	0.015
050210	0.020	0.008	-0.006	050516	0.235	0.041	0.013
050212	0.208	-0.008	0.007	050518	-0.005	-0.045	-0.009
050215	0.159	0.040	0.014	050521	0.019	0.030	0.009
050217	0.108	-0.026	0.006	050523	-0.058	-0.006	0.011
050219	0.131	-0.002	0.004	050525	0.163	0.090	0.012
050222	0.112	0.011	0.002	050528	0.067	0.009	-0.007
050224	-0.045	-0.035	0.017	050530	-0.010	-0.004	0.012

APPENDIX 2 - CONTINUED

EV LAC SEP 21, 1974 (CONT.)

TIME	U	B	R	TIME	U	B	R
050532	0.080	0.008	0.008	050616	0.052	0.049	0.007
050534	0.229	0.052	0.015	050618	0.024	-0.005	0.003
050537	0.063	0.099	-0.000	050620	0.125	-0.015	0.015
050539	0.182	0.054	0.006	050623	0.131	-0.019	0.001
050541	0.088	0.087	0.003	050625	0.239	0.035	0.019
050544	0.115	0.058	-0.002	050627	0.213	0.121	0.001
050546	0.054	-0.006	0.010	050630	-0.009	0.021	0.015
050548	0.121	-0.040	0.013	050632	0.087	0.043	0.012
050551	0.027	0.070	0.008	050634	0.008	0.064	0.003
050553	0.131	0.043	0.010	050637	0.060	-0.002	0.014
050555	0.084	0.004	-0.002	050639	0.150	0.036	0.015
050557	0.032	0.064	0.003	050643	0.148	0.029	0.018
050600	-0.066	0.005	0.014	050646	0.124	0.004	0.009
050602	0.050	0.073	0.016	050648	0.212	0.044	-0.011
050604	0.064	-0.002	0.019	050650	0.097	-0.015	0.016
050607	0.122	0.088	0.016	050653	0.027	0.007	-0.004
050609	0.089	-0.027	-0.005	050655	-0.031	0.038	0.013
050611	-0.056	0.013	-0.006	050657	0.091	0.082	0.010
050614	0.085	0.070	0.015	050700	0.090	0.031	-0.005

APPENDIX 2 - CONTINUED

AD LEC APR 18, 1975

TIME	U	B	R	TIME	U	B	R
024020	0.106	0.019	0.019	024157	0.362	0.060	0.012
024022	0.156	0.052	0.016	024159	0.327	0.043	0.009
024025	0.097	0.055	0.019	024201	0.376	0.094	0.014
024027	0.261	0.065	0.017	024204	0.240	0.040	0.005
024029	0.258	0.084	0.024	024206	0.365	0.017	0.006
024032	0.260	0.074	0.022	024208	0.246	0.025	0.009
024034	0.237	0.062	0.019	024211	0.301	0.043	0.012
024036	0.455	0.068	0.024	024213	0.211	0.043	0.018
024039	0.492	0.078	0.030	024215	0.188	0.047	0.018
024041	0.539	0.119	0.028	024217	0.262	0.066	0.014
024043	0.541	0.085	0.021	024220	0.216	0.076	0.026
024045	0.580	0.075	0.025	024222	0.236	0.101	0.011
024048	0.647	0.081	0.028	024224	0.200	0.092	0.017
024050	0.657	0.073	0.022	024227	0.193	0.025	0.018
024052	0.884	0.110	0.025	024229	0.234	0.092	0.012
024055	0.670	0.104	0.025	024231	0.240	0.024	0.020
024057	0.680	0.106	0.021	024234	0.230	0.055	0.017
024059	0.754	0.138	0.010	024236	0.155	0.005	0.017
024102	0.735	0.119	0.022	024238	0.120	0.064	0.028
024104	0.795	0.099	0.012	024240	0.234	0.077	0.032
024106	0.540	0.081	0.016	024243	0.124	0.086	0.042
024108	0.446	0.073	0.008	024245	0.078	0.085	0.038
024111	0.661	0.055	0.011	024247	0.185	0.057	0.029
024113	0.434	0.081	0.017	024250	0.185	0.041	0.038
024115	0.525	0.031	0.003	024252	0.311	0.102	0.029
024118	0.542	0.068	0.012	024254	0.166	0.030	0.029
024120	0.574	0.052	0.005	024257	0.107	0.019	0.035
024122	0.426	0.081	0.017	024259	0.200	0.011	0.023
024125	0.393	0.096	0.017	024301	0.105	0.030	0.034
024127	0.370	0.058	0.019	024303	0.025	0.063	0.039
024129	0.287	0.082	0.018	024306	0.188	0.078	0.021
024131	0.260	0.058	0.025	024308	0.102	0.087	0.022
024134	0.544	0.094	0.021	024310	0.144	0.066	0.026
024136	0.311	0.081	0.027	024313	0.184	0.031	0.030
024138	0.377	0.087	0.026	024315	0.267	0.066	0.032
024141	0.339	0.063	0.017	024317	0.124	0.074	0.021
024143	0.423	0.063	0.026	024320	0.095	0.045	0.031
024145	0.302	0.082	0.030	024322	0.175	0.093	0.026
024148	0.241	0.043	0.021	024324	0.118	0.066	0.024
024150	0.335	0.068	0.017	024326	0.131	0.081	0.034
024152	0.340	0.068	0.018	024329	0.219	0.006	0.026
024154	0.341	0.052	0.012	024331	0.167	0.005	0.032

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In August, 1972 he met and during the summer of 1976 will marry Miss Susan Ziebarth.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Frank B. Wood

Frank B. Wood, Chairman
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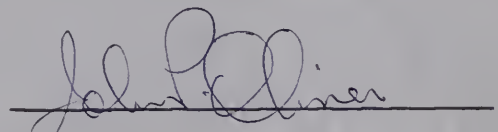

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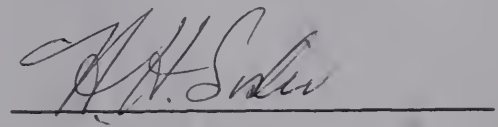
This dissertation was submitted to the Graduate Faculty of the Department of Physics and Astronomy in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1975



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